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EDITORIAL.

ITEMS AND NOVELTIES.

On Deep Sea Sounding.—Sir William Thomson has lately communicated to the British Society of Telegraphic Engineers, a paper upon his new method of deep sea sounding by means of piano-forte wire. We condense the following description of it from the *Telegraphic Journal:*

Wire is better than rope for this purpose, because of the smallness of its area and the smoothness of its surface. The size employed is No. 22 of the Birmingham wire gauge, weighing 14½ pounds to the nautical mile, and bearing a weight of 230 to 240 pounds before breaking. Messrs. Johnson of Manchester made for him a piece of this wire three miles long, drawn from a single ingot of crucible steel, and capable, by actual test, of sustaining the above weight. The importance of having the sounding wire in one piece is very great, since splicing is almost an impossibility. At first the two ends of the wire were twisted together and solder was run between them; yet on testing the joint, the wire itself broke close to it, at a strain from 10 to 20 pounds less than, under other conditions, the wire sustained. The sudden change in area is an element of weakness; and to avoid it, an exceedingly gradual commencement of the pressure must be secured. This is effected by a splice at least two feet long. The two wires are placed parallel for this distance, seized in the middle,

and the two ends successively turned round the contiguous straight portion of wire. If the wires be previously coated with marine glue, to increase the surface friction, and the ends be kept down by a serving of twine, the splice is capable of sustaining as great a load as the wire itself. The next difficulty to be overcome was in the apparatus for hauling in the wire. Originally a wheel or whim a fathom in circumference, was used, the first sounding made with it being one of 2700 fathoms in the Bay of Biscay. After hauling in 1500 fathoms, the wheel labored and the last 800 fathoms were recovered with great difficulty. The first remedy applied was to stop the process after say 20 fathoms, to take the strain off the wire, and to ease it round the wheel; but, beside being very tedious, it did not give accurate results. In the American Navy, the weight is automatically detached upon striking the bottom and then the wire is easily pulled in. But as it was very undesirable to lose 30 or 35 pounds of lead or iron at every sounding, the author contrived an apparatus by which the weight could always be recovered; at least from depths not exceeding 3000 fathoms. When a sounding is made from a ship hove to for the purpose, a serious difficulty is encountered in the tendency of the wire to kink. This is obviated by fastening the weight to the ring or clamp at the end of the wire, by means of 15 fathoms of cod line, the clamp itself weighing about 4 pounds. When the weight strikes the bottom, the paying out of the wire ceases before the clamp strikes; hence there is no wire coiled on the bottom and there is no kinking. In order to arrest the paying out of the sounding wire at the proper time, a measured resistance is applied systematically to the wheel, which resistance is always to be more than enough to balance the weight of the wire out. For example, let this resistance exceed by 10 pounds the weight of the wire paid out. The sinker weighs 30 and the clamp 4 pounds. Hence 24 pounds represents the moving force; a force sufficient to reach the bottom at 3000 fathoms, in three quarters of an hour. By means of a time-counter, narrowly watched by the person in charge, three pounds is added to the brake for every 250 fathoms of wire paid out; this is 12 pounds for every thousand fathoms, which is about the weight in water of this length of wire. Now, when the weight strikes the bottom, instead of there being a downward strain on the wire of 24 pounds, there is a resistance to its motion of ten pounds. A few turns of the wheel—two or three at the most—and the motion is stopped; and, long before the clamp gets to the bottom, there being 10 fathoms of line between it and the sinker,

the wheel stops. The wire-wheel is then run back, a spun-yarn stopper is put on the wire, the strain is taken off, and the wire is carried over the top of the large wheel, one coil being enough for 3000 and 2 for 4000 fathoms. A pulley with a sharp V groove is put on each side; and then with a snatch-block, and with a deck ten fathoms inboard, three men hauling on each side can haul up at the rate of 8 nautical miles an hour. Moreover, by a suitable arrangement, the excess of stress caused by a heavy sea, may be regulated to the force exerted in hauling in.

In relation to the adoption of this method of sounding in the British Navy, Sir. Wm. Thomson goes on to say: "I think it highly desirable that this process should be taken up by our own admiralty. There is a great tendency to the other side. I have a semi-official letter to the effect: 'When you have your apparatus perfected, we may be ready to try it.' I may say that it seems a little strange that, after my having intimated, in the month of June, 1871, the perfect success of wire for sounding in depths of 2700 fathoms, the Challenger was allowed to go to sea without taking advantage of this process, and that a year and a half later, I should be told: 'When you have perfected your instrument we will give it a trial.' The American Navy looked upon the matter with different eyes and certainly in a different spirit. They moved those who had the direction and they took it up with the very greatest zeal. They found my apparatus full of defects, but they never asked me to perfect it, but they perfected it in their own way and they obtained results. I went on independently in another line and made a considerably different apparatus from that which is now being used by the Americans; but I certainly was very much struck by the great zeal and the great ability which the American naval officers showed in taking up a thing of this description which had once been proved to be good, and charging themselves with improving the details and making it a workable process."

The paper closes with an account of the method of making flying soundings with wire. During the Hooper telegraph expedition from Pernambuco to Para, soundings were taken every two hours without stopping the ship. A 30 pound weight was hung by two fathoms of cord (though five would have been better) to the clamp, and the wheel was let go with a resistance of about 8 pounds. When the ship was moving 4½ knots, the cable was paying out at 6 knots; and after 150 to 175 fathoms had run out, the wheel would suddenly almost cease to turn, and was then stopped. In this way flying soundings were

made in water 150 fathoms deep, the ship going 6 knots per hour. The wire is protected from rust either by immersion in oil, after the American plan, or in caustic soda, as on board the Hooper.

The Sczaroch, a new Russian projectile.—A new shell, under the above name, has just been adopted for the Russian artillery, which seems to have certain advantages. When the old spherical shell was replaced by the elongated shell, now entirely in use, the argument was the necessity of obtaining a higher initial velocity, which was possible only with rifled guns. There was not an artilleryman who did not regret the sacrifice thus made of the ricochet shot; a shot extremely useful in certain cases, and apparently quite impossible with an elongated projectile. Some two years ago a Russian officer devised a shell which was a time or a percussion shell and at the same time could give the results of a ricochet shot. The sczaroch, as it is called, is an elongated shell, the head of which is completely spherical; a round shell upon the end of an iron cylinder. The two parts are united together by a comparatively slight thickness of metal. When fired, the sczaroch leaves the gun like an ordinary shell; but when it bursts, the cylindrical part alone flies in pieces, while the spherical head continues its flight intact and may ricochet for hundreds of yards further. The advantage of such a shell against artillery, for example, is very great. After bursting and scattering its fragments among the guns of the enemy, the head goes on to plunge into the infantry still further back. It is only to be used in Russia however, for cannon of moderate size.

On the Action of Spiegeleisen in the Bessemer Process.—An investigation into the function performed by the spiegeleisen when added to the Bessemer charge has been made by Bender. A portion of the metal, when ready for the charge of spiegeleisen, was run into a white hot clay mould and slowly cooled. Its structure was coarsely crystalline, a condition favored by the oxygen contained in it. It was brittle under the rolls, but tough and hard under the chisel. Upon analysis, it contained 0·35 per cent. of oxygen. The action of the spiegeleisen upon the iron, the author then calculates as follows: The charge of 3,500 kilograms lost ten per cent. of slag, leaving 3,150 kilograms of metal, which at the above percentage, would contain 11·02 kilograms of oxygen. To this, 325 kilograms of spiegeleisen was added, containing five per cent. of carbon and eight per cent. of man-

ganese; i. e., 16·25 kilograms of carbon and 26 kilograms of manganese. Since 55 parts of manganese takes up 16 of oxygen 26 kilograms requires 7·67 kilograms; leaving 3·45 kilograms of oxygen. Moreover, as the carbon is also active, as the flame shows, the 3·45 kilograms of oxygen would require 2·58 kilograms of carbon, which, subtracted from the 16·25 kilograms contained in the spiegeleisen, leaves 13·67 kilograms of carbon. Before adding this, the Bessemer metal contained 0·08 per cent. of carbon, equal to 2·52 kilograms; hence it contained afterward 16·2 kilograms. Upon analysis, the steel obtained contained only from 0·15 to 0·20 per cent of manganese; hence the author believes that since both the manganese and the carbon added in the spiegeleisen, operate upon the oxygen, the excess of manganese and its equivalent of carbon pass away in the slag, leaving only the above quantity—0·15 to 0·20 per cent—combined in the steel. As 0·15 per cent. equals 5·17 kilograms of manganese, equivalent to 1·12 kilograms of carbon, the carbon left would be (16·2–1·12) 15 kilograms to about 3,450 kilograms of metal, or 0·43 per cent. Actual experimental determination gave 0·40 per cent. carbon.

It appears, therefore, that from three-fourths to four-fifths of the manganese introduced by the spiegeleisen, is lost in the slag; whether the small portion which the steel retains is of any advantage to it or not, is yet undecided. Moreover, the silicon is slightly increased, and the sulphur slightly diminished by the addition of the spiegeleisen. The author maintains that the spiegeleisen may be replaced with advantage, both as to quality and quantity of the product, by a good white carburetted iron. The great difficulty with both, however, lies in the fact that the carbonic oxide formed by the carbon which they contain, in acting on the oxygen of the Bessemer metal, appears to be dissolved in the liquid metal and to be evolved on solidification. This "blowing" as it is termed, is a serious injury to the metal. The author hence thinks it desirable to replace the carbon by a substance which forms when united with oxygen an easy fusible slag instead of a gaseous product.

On the Temperature obtained in Freezing Mixtures.—One of the results obtained by Berthelot in his admirable researches in thermo-chemistry—and by no means one of the least important, we may add—is the determination of the law according to which refrigerating mixtures act, thus rendering it possible to ascertain by a very

simple calculation exactly what temperature can be obtained. If, for example, sulphuric acid of specific gravity 1·78, crystallized, be mixed with snow or pounded ice, three thermic effects are produced; first the acid liquefies, absorbing heat; second, the ice melts, also absorbing heat; and third, the two liquids unite, evolving heat. The actual figures are as follows, three parts (58 grams) of acid and eight parts (153 grams) of ice, both at 0°, being mixed:

Melting of the crystallized acid	— 1840 calories	
" " " ice	—12155	—9015
Union of acid and water	+ 4900	

211 grams of the mixture absorb then 9015 calories of heat. If now this number be divided by the product of the weight, 211 grams, and the specific heat of the mixture, 0·813, which is 171·5, the quotient is — 52·6°, the final temperature obtained. If the substances be cooled to — 20° before mixture, the final temperature is — 62°. In the last century, mercury was frozen by a mixture of liquid sulphuric acid and snow. Theory shows that when one part of sulphuric acid containing one-fifth water, is mixed with three parts of snow, both cooled to — 7°, the final temperature is — 51°. So calculation and experiment agree that when nitric acid is mixed with twice its weight of snow the temperature is lowered to — 56°. Of the three ways of producing cold: (1) by converting a solid or a liquid into a gas, (2) by liquefying a solid either by contact with a liquid or another solid, or (3) by chemical action in solution, producing a substance which absorbs more heat than the bodies originally present—the first is immensely the most effective. Theory shows that the evaporation of ether should produce a cold of —192°; of carbon disulphide, — 530°; of liquefied ammonia — 460°; of hyponitrous oxide (liquid) — 440°. Were it not for the fact that the tension of the vapor evolved from these liquids soon becomes so feeble that the cold produced by evaporation is balanced by absorption from surrounding bodies, a fact which prevents the production of a temperature more than 100° below the boiling point of the liquid, it would undoubtedly be possible practically to attain in this way very low temperatures, perhaps even the absolute zero, generally fixed at —273°.

Postal Cards in the Different Countries of Europe.—The idea of postal cards is attributed to Dr. Emanuel Hermann, professor in the Vienna Military Academy. They were introduced into England in 1870, at the price of one half-penny, (one cent), the letter postage being one penny. The average circulation there of these post-

al cards has risen to a million and a half a week. More than seventy-five millions were sent in 1871, and this number was exceeded in 1872. The number of letters mailed, so far from diminishing in consequence of the introduction of the cheaper postal card, as had been predicted, has actually increased; in place of 863 millions of letters carried in 1870, 915 millions were transported in 1871, an increase of 52 millions. This enormous increase raises the mean percentage of the annual progression, which, for the five previous years, from 1866 to 1870, had been four per cent, up to six per cent.

In Germany, the introduction of card-correspondence was decreed in June, 1870, and it began practically a month later. The advantages offered by it caused it to be rapidly extended, although the price had been fixed at that time at one groschen (2½ cents), the same as letter postage. On the first of July, 1872, this price was reduced to one half a groschen (1¼ cents), letter postage remaining as before. Here also the introduction of the postal card has not interfered with the number of letters mailed, which, in place of 205 millions in 1870, became 240 millions in 1871. A most valuable addition to the postal card system, moreover, has been adopted in Germany, and has extended to Holland, to Belgium and to Switzerland. Beside the simple postal card, a double one is also issued, having a pre-paid card attached for the answer. The two cards correspond in size, each bears the stamp and they are sold at a double price.

In Switzerland, the postal card system was introduced October 1st, 1870, the price being five centimes (one cent). In 1871, 1, 713,710 cards were sent. The letters mailed increased from 20,477,844 in 1870 to 22,563,351 in 1871.

Belgium adopted postal cards July 1st, 1871, the price being five centimes (one cent). At first the system was local, but it has since become general. The number of letters sent, has, as in other countries, steadily increased. On the first of January, 1873, the Minister of Public Works, under whose direction are all postal and telegraphic arrangements, ordered the issue of double postal cards having a pre-paid card for the answer.

Norway has had postal card correspondence since January 1st, 1872, the price at first being that of ordinary letter-postage, 9 skillings (2·9 cts). It has since been reduced to 2 skillings within the same postal district. The results generally are regarded as satisfactory.

In Sweden, the price of the postal-card at first fixed at 12 ore (3½ cts), has been reduced to 10 ore (2·8 cts). In Denmark, the system

was adopted April 1st, 1871. The general card costs 4 schillings (2·4 cts) and the district card 2 schillings (1·2 cts).

In Russia, postal cards were introduced January 1st, 1872. The general card is furnished at 5 kopecks (4 cts) and the district card at 3 kopecks (2·4 cts.) In Austria, the postal card costs 2 kreutzers (one cent.) The system was adopted in October, 1869, and the first year eight millions of cards were sold.

Spain has decided upon postal cards; Greece and Portugal are about to issue them; and in Italy the same course has been resolved upon. Turkey alone has failed to see the advantages of the postal system and to adopt it.

On a New and Constant Thermo-Electric Generator. — The direct production of electricity from heat, and its utilization in practice as a source of power, has not, until now, been a commercial success. Unquestionably the best thermo-electric combination thus far obtained is that of Mr. Farmer, of Boston, in which an alloy of zinc and antimony constitutes the positive, and German silver or copper the negative plate. Such an electro-motor was exhibited at the Paris Exposition of 1867, and excited great interest. The difficulty, however, in their use on the large scale lies in the fact that when in action they lose their activity rapidly and "run down." Clamond has lately investigated the reason of this, and he finds it to be due to two causes: first, to the oxidation of the surfaces of contact of the two bars under the influence of the heat; and, second, to the cracking of the crystalline bar and its breaking into transverse sections. While, therefore, the electro-motive force of the apparatus undergoes no diminution, the internal resistance is so increased as to render the combination useless after a little time. The first of these difficulties Clamond has overcome by making some oblique cuts in the end of the flexible plate, and bending the intermediate tongues alternately to either side. When the melted metal is poured round this plate it flows into the spaces thus enclosed, and makes a more perfect contact. The second cause of deterioration was not so easily overcome. Annealing was found to be of no use, and it was finally ascertained that to render the bars homogeneous, crystallization must be prevented. This was effected by heating the moulds in which the zinc-antimony bars were cast, to a temperature near that at which the alloy fuses, and by pouring in the metal at a temperature near its solidifying point. In this way, using the zinc-antimony alloy in connection with strips of

iron, the author has succeeded in constructing a thermo-electric generator, which remained in action in the laboratory of M. Jamin, at the Sorbonne, for six entire months without deterioration. This apparatus consisted of three rings, each composed of ten pairs of bars, arranged radially. In the interior cylindrical space was placed an earthenware tube full of holes, serving as a gas-burner. The entire apparatus weighed about 14 pounds, and at an expense per hour, of six cubic feet of gas, costing in Paris one cent, it deposited two-thirds of a troy ounce of copper; being equivalent to a Bunsen cell seven inches high.

Duchemin's Circular Compass.—A new compass has been invented in France by M. Duchemin, the magnetic force of which resides, not in a bar or needle, as in the ordinary instrument, but in a flat steel ring, magnetized, with its poles at two opposite extremities of the same diameter. This ring, supported upon an aluminum traverse, pivoted on agate at its centre, has attached to it the ordinary compass card, and acts promptly and efficiently. The author claims for it the following advantages: (1) a magnetic power, double that of a needle whose length is that of the diameter of the ring; (2) two neutral points instead of one, as in the needle; whence it happens that none of the magnetism escapes, and that strong sparks like those from the Holtz machine do not derange the poles; (3) a better and more prompt performance of the compass, the card seeming to float, as it were, in a liquid; (4) a large increase in the sensitiveness of the instrument; (5) the ability to regulate the magnetic intensity of the ring, and thus to compensate for local causes. This is effected by means of a second magnetized steel ring, smaller than, and inside of, the first, the position of which—and therefore its neutralizing action—may be easily adjusted. Under the direction of the Minister of the Marine, a trial trip of the new compass was made on the steamboat Faon with very satisfactory results. M. Duchemin now proposes, as an improvement, the use of a set of such rings, forming a spherical or spheroidal system of still greater magnetic power.

The Pernot Rotary Puddling Furnace.—A new puddling apparatus, designed and constructed by M. Pernot, has been brought to the notice of the Society of Civil Engineers of France. In this furnace, charges of 18 cwt. of fine iron obtained from charcoal pig, or 22 cwt. of ordinary iron made from common pig, are obtained at each operation. The production varies according to the nature of the pig

employed, ranging from double to treble the quantity obtained in an ordinary puddling furnace. With pig iron from Pouzin we have made 4½ tons per run, which operation lasts about two hours. One ton of this pig gives nearly 19 cwt. of bars. It is a curious sight to see seventeen or eighteen balls drawn successively from the same furnace, the last ball being as hot and as free from cracks as the first one, and remarkably clean in appearance. The cost of production, compared with that of ordinary furnaces, is in favor of the new system. The process of M. Pernot is now a practical one, and carried on with the certainty of obtaining the different products expected from a puddling furnace, such as fine iron from charcoal pig, ordinary iron, and puddled steel. In the old furnace it is always the same layer of iron which is subject to the action of the scoriæ, and the parts touching the bed and bottom do not come within the influence of this action. In the rotary furnace, with inclined bed or bottom, the different particles come successively in thin sheets just as they are dragged along by the rotary motion to the upper region of the furnace, and there they are not submitted too long to the oxidizing action, because immediately after they dip down again into the bath in the lower part of the furnace. The same reasons produced very complete heating of the whole mass of metal. M. Pernot has furnaces with rotary bed or bottom for the fusion of steel, by adding to it the superheating obtained by means of gas generators and Siemens regenerators. To say that he has succeeded would not be wholly correct. This process, from the peculiar mode of loading, and from the action of rotation which gives a better heating and more rapid decarburation, has so much improved the condition in which cast steel can be obtained that there is no longer any analogy with the old methods. The same gas producers which were used for a Siemens-Martin furnace are now applied to this new furnace, giving twice as much steel in the same time as before, and with a corresponding economy in the working expenses. —*Iron Age.*

Bibliographical Notices.

TRI-NITRO-GLYCERIN, AS APPLIED IN THE HOOSAC TUNNEL, etc. By GEORGE M. MOWBRAY, Operative Chemist. *With thirteen*

illustrations, tables, and appendix. Third Edition, re-written, 8vo. *pp.* 124. *New York,* 1874. *D. Van Nostrand.* Mr. Mowbray stands confessedly at the head of nitro-glycerin manufacturers in this country. Thoroughly trained in early life as a manufacturing chemist, he has so successfully applied his knowledge that the manufacture and use of this terrible explosive agent have been rendered almost absolutely safe. In proof of this assertion is the fact that, during the past six years, he has produced, at the Hoosac Tunnel alone upwards of five hundred thousand pounds of nitro-glycerin; and this with only two accidents, both of them attributable to the grossest carelessness on the part of workmen. We are glad therefore to have a monograph from his facile pen upon this most efficient explosive, so essential, now-a-days, to all enterprises requiring the excavation of rock. Mr. Mowbray's operations on the large scale, were commenced at North Adams, in the winter of 1867–8, under a contract with the Massachusetts Tunnel Commission. They have continued uninterruptedly up to the present time, and have been carried forward with an energy, an ability, and a persistency which renders their great success no secret. In the book before us—which has already reached its third edition—he has given us an admirable statement of facts. The opening chapter is devoted to a sketch of the difficulties attending the first introduction of nitro-glycerin in practice, by reason of the fearful explosions in New York, Panama, and San Francisco, of the impure product of Nobel. The author then discusses the relative value of gun cotton and of nitro-glycerin; states the results of the experiments already made with the latter at the Hoosac Tunnel, in Erie Harbor, at Dimon's reef and Hallet's Point, N. Y., and in the oil wells of western Pennsylvania; describes the various processes for the manufacture and the analysis of nitro-glycerin, and of the various mixtures of this substance with absorbents, which have been proposed as substitutes; gives an account of the entire method of working with nitro-glycerin at the Hoosac Tunnel; corrects some errors concerning this substance, to be found in current literature; treats of the various electric and magnetic machines by which the explosion may be effected, and of the various fuses which may be employed for the purpose; and closes with some succinct and excellent instructions for handling and using the nitro-glycerin. One cannot read these interesting pages without being impressed, not only with the great value, not to say the absolute necessity of, nitro-glycerin in all tunnelling operations, but also with the indefatigable labors which have rendered its use on this immense scale, possible. It is to Mr. Mowbray, beyond question, that we owe the determination of the conditions of its safety. Recognizing at once, the important chemical fact that the most efficient, as well as the safest, nitro-glycerin, required the use of the strongest acids (acids, too, which, not being found in commerce had to be made upon the premises) he devised a most ingenious process for using these acids with economy and safety by blowing a stream of cold air through them while the glycerin

enters. Thus originated his tri-nitro-glycerin, by far the safest, as it is the purest and the strongest, which is now in commerce. Moreover, the care employed in having the glycerin pure and dry, and in having the acid mixture thoroughly cooled when the glycerin is run into it, contributes essentially to the result. His product is therefore a colorless oily liquid, of specific gravity 1·6 at 60° F. It is insoluble in water, soluble in alcohol and ether, has no odor, but has an aromatic taste, though the minutest quantity on the tongue causes, in a few minutes, a severe but transient headache. Unlike other nitro-glycerins, the products of its explosion are neither offensive nor deleterious in their action upon the workmen. Another important point, however, is here to be noted. After production, the nitro-glycerin is placed in earthenware jars holding sixty pounds and kept at the temperature of 70° F. for seventy-two hours, to fine. It is then run into square tin cans holding 56 pounds, for packing. Now, it was by a fortunate accident that Mr. Mowbray learned the secret of subsequent safety, and ascertained that nitro-glycerin is inexplosible when solid. Next to its purity therefore, nitro-glycerin owes its safety during transportation to its being previously frozen. The tin cans are therefore placed for 48 hours in ice; the nitro-glycerin solidifies and, packed in a box with sponge upon the bottom, resting on four rubber tubes which come up over the cans, and well iced, it may be transported by wagon as safely as butter.

It may easily be seen from the above statements that Mr. Mowbray deals with a subject which is at once fascinating by its attendant risks and instructing by its practical value. His book is entertainingly written and cannot fail to be of great service, not only to him as a manufacturer, but also to those enterprises which, like the Hoosac and St. Gothard tunnels, require the energy of nitro-glycerin to carry them forward to successful completion.

TABLES FOR QUALITATIVE CHEMICAL ANALYSIS, *with an introductory chapter on the course of Analysis. By Professor* HEINRICH WILL *of Giessen, Germany.* Second American, from the Ninth German Edition. Edited by CHAS. F. HIMES, PH. D., Professor of Natural Science, Dickinson College, Carlisle, Pa., 8vo., pp. 22, and Tables XIV. Philadelphia, 1874. Henry Carey Baird.

Professor Will's Analytical tables are too well known to the Chemical profession to need any detailed description of them. They have not only the great advantage which tables always afford, of presenting to the eye at a glance the complete analytical classification of the substances treated, but they have a value purely their own, over any other book in general use in the fact that all the rare as well as the common elements are included in the reactions given. Prof. Himes has done his work excellently and has made some valuable additions. He acknowledges some suggestions from Prof. Genth, of the University of Pennsylvania.

Franklin Institute.

HALL OF THE INSTITUTE, June 17th, 1874.

The meeting was called to order at 8¼ P.M., the President, Coleman Sellers, in the chair.

The Secretary being absent the President appointed J. B. Knight as Secretary *pro tem.*

The minutes of last regular meeting, held May 20th, 1874, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held June 10th, donations to the Library had been received as follows:—

Journal of the Society of Arts, Vol 22, Nos. 1115 to 1118. London. From the Society.

Journal of the Statistical Society for March, 1874. London. From the Society.

Journal of the Chemical Society, Vol. 12, February to April, 1874, with index for Vol. 11, 1873. London. From the Society.

Proceedings of the Royal Institution of Great Britain, Vol. 7, Part 1–2, 1873, with list of Members, Officers, etc. London. From the Royal Institution.

Monthly Notices of the Royal Astronomical Society, Vol. 34, No. 6. London. From the Society.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, April, 1874. Paris. From the Society.

Zeitschrift des Ingenieur und Architekten-Vereins zu Hannover, Vol. 19, Part 4, 1873. Hannover. From the Society.

Penna. Report of the Bureau of Statistics of Labor and Agriculture, 1872–1873. Harrisburg. From the Bureau of Statistics.

Address of Henry A. Oakley, at the 8th Annual Meeting of the National Board of Fire Underwriters, held April 22d, 1874, with Reports of Stephen Crowell and Thos. H. Montgomery, and the Report of the Committee on Legislation and Taxation. New York, 1874. From the Franklin Fire Insurance Co., Philadelphia.

Bulletin of the National Association of Wool Manufacturers, January, March, 1874. Boston. From the Association.

Report of the Superintendent of the Coast Survey, during the year 1870. Washington. From E. P. Patterson, Superintendent.

Mr. Tatham, Chairman of the Committee on Exhibition, made the following report:—

"The Sub-committee on Premiums and Awards, having performed the work it was appointed to do, a motion will be made to dissolve it at the next meeting of the Committee on Exhibition.

This Sub-Committee was appointed to consider whether or not a classified list of exhibits and premiums should be published beforehand, what the premiums should be, and who should make the awards, the result of their action is embodied in the printed rules.

This statement is made publicly in order to exclude the idea, which might arise from the name of the Sub-Committee, that it has anything to do with the awards of the Judges."

Mr. Hector Orr read a paper on Street Pavements, in which he takes issue against all the present modes of paving roadways with stone, and strongly favors the use of wood. He said that the great want of the age is some street pavement that will *absorb* the concussion of vehicles passing over it.

Mr. Orr exhibited a specimen of white cedar, which had lain in the ground, as a railroad sleeper, for twenty-five years, and which is still sound. He recommended the use of white cedar for street pavements, as this would have the excellent quality of durability.

Dr. Rogers asked Mr. Orr if it was contemplated to use the cedar wood lying as a sleeper, and stated that the factor of durability as a sleeper in city railroad track was quite different from that as a pavement, and that durability in the former position does not prove that it will be so in the latter.

Mr. Close stated that he was quite positive that there are no hemlock sleepers in the street railways of Philadelphia, and asked Mr. Orr how he got his information on this point.

Mr. Orr replied, that in passing a portion of Old York Road where some repair was being made, he was told by one of the workman that the sleeper was hemlock.

Mr. Wm. B. Levan then read a paper entitled Horse Power of Steam Boilers, being a description of the Steam Engines and Horizontal tubular boilers in use by the Cocheco Manufacturing Co., Dover, N. H., and the details of a test of same, showing the following results:—

Water evaporated per pound of anthracite coal, 10 lbs. Water evaporated per indicated H. P., 18 lbs. Indicated H. P. for each

cubic foot of water evaporated 3·4. Some remarks were offered by Messrs. Wiegand and Lovegrove.

The Secretary then read a paper by Mr. John Russell, upon a new process of fluxing and smelting the ores of precious metals, in which it is claimed that such ores can be fluxed at a cost not exceeding $1.00 per ton.

Dr. Rogers stated that he had not seen the process, and the paper gave no indication of what it consists, but he hardly thought such ores could be fluxed for $1.00 per ton; but if it can be done for anything like the cost named, it will certainly give a strong impetus to the production of the precious metals.

Dr. Koenig wished to know what the process was, as he saw no indication of originality, so far as it was described in the paper. If it is intended to treat all ores alike it certainly would be a failure, as it is well known that ores from different mines require different treatment, and to attempt to flux all alike would be like giving some patent medicine for the cure of all diseases.

In reply Mr. John S. Crawford stated that the process is a secret, but it was the intention of the inventor, at some future day, to lay the whole subject before the Institute.

Dr. Rogers stated that the Institute does not undertake to pass upon processes in which a secret is maintained, and recommends that the matter rest until full information is given.

The President stated that the presenting of the paper was out of order, not having passed the Committee on Meetings, but as it came to him, coupled with the names of prominent members of the Institute, he had directed it to be read.

The Secretary *pro tem.* then exhibited specimens, showing a new system of calking steam boilers, and other vessels made of sheet-metal; the invention of Mr. Jas. W. Connery, of this city, and called "Concave Calking." Also a number of specimens taken from condemned and exploded boilers, showing the injury done the metal by the old system of calking. By the new system the edges of the plates are planed, or chipped in the usual way, and a calking tool of half the thickness of the plates, having a semicircular end, is used to upset the edge of the overlying sheet, care being taken to prevent the tool coming in contact with the under plate. It is claimed that the evil known as grooving and consequent weakening of the plates, is thus entirely obviated.

Also a model of a mill for grinding wet substances, such as paints

ink, and rubber, the invention of Mr. L. P. Dodge, of New York. This mill consists of two rollers, of greatly different diameters, preferably 3 to 1, with the surfaces touching, and geared to revolve at the same number of revolutions, thus causing the surfaces to slip one on the other.

Under the head of Unfinished Business, the amendment to the By-Laws, recommended by the Board of Managers, at the last Monthly Meeting, was called up, and after some discussion as to its exact bearing, by Messrs. Rogers, Le Van, Sewall, Lovegrove, Wiegand, Grimshaw, and Mitchell, the amendment was adopted with but one dissenting vote, as follows:—

Amendment to the By-Laws, Art. 2, Sect. 7.

"Members whose yearly dues are in arrears for three years, shall be considered as having resigned, and the Actuary is directed to strike their names from the list of members."

Mr. Close stated that some months ago he presented a resolution which was referred to the Committee on Science and the Arts, calling attention to the law of Congress, then just passed, allowing certain steamboats to carry 150 lbs. pressure in boilers of 42 inches diameter, made of ¼ inch iron, and inquired what had become of it.

The Actuary replied that it was referred to a Sub-committee of the Committee of Science and the Arts, but that, as several of them could not serve, a new committee would shortly be appointed.

The President read a letter from Mr. W. W. Evans, of New York, presenting to the Institute a handsomely printed copy of Brougham's Life of Washington, embellished with a colored photograph copy of a miniature portrait of Washington, painted from life by Mrs. Sharpless.

On motion of Mr. J. E. Mitchell, the President was directed to convey to Mr. Evans the thanks of the Institute for his donation.

Messrs. Hale, Kilburn & Co. placed the eulogy and portrait in a handsome frame, which they presented to the Institute.

On motion, a special meeting of the Institute was called for Wednesday, the 24th inst., at 8 o'clock P.M., for the purpose of witnessing the operation of Hall's Pulsometer, applied as a condenser for ordinary high pressure steam engines, and of an Automatic Relief valve for steam fire engines, the invention of Mr. John E. Prunty, of Baltimore.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary pro tem.*

Civil and Mechanical Engineering.

THE THEORY OF AERO-STEAM ENGINES.*

By J. A. Henderson, M. E.

Among the possible forms of heat engines, it is probable that only those using steam and air as their working fluids, will continue as heretofore to be largely applied to practical purposes. The latter include gas engines, as the coal gas used in them merely forms the supply of fuel, and constitutes but a small fraction of the whole of the air required to act as a medium in the conversion of its heat of combustion into mechanical energy. A late publication refers to a French invention in which the expansion of oil undergoing changes of temperature, furnishes the motive force, and theoretically all liquids and even those solids, as certain of the metals, adapted to withstand the range of heat, might be so applied, but the many difficulties incurred in their practical use and construction, have prevented and will probably continue to prevent their introduction. The same may be said of ammonia engines, and bisulphide of carbon or other engines, where, in addition, special precautions have to be taken to guard against loss of their comparatively expensive working substance.

*[Editorial Note—We publish the following paper as the first theoretical treatise on the Aero-Steam Engine which has appeared to complement the work of the late Professor Rankine on other heat engines. The article is abridged from a graduating thesis at the Stevens Institute of Technology, at the close of the college year 1873-73.

The author, who has since been employed by the Delaware Iron and Ship Building Co., Chester, Pa., has just accepted a position at the Baltic Iron Works, St. Petersburg, Russia, under Mr. E. J. Reed, C. B., the distinguished British naval architect. His absence from the country has prevented his revision of the proofs. The paper has, however, been through the hands of his instructor, Professor Thurston, and we trust will be found to contain no serious errors.

The interest shown by engineers in the recent attempts of Warsop and others to introduce this engine will fully justify the publication of its theory, although the paper will be found more purely mathematical than those which we are accustomed to give a place to in the Journal of the Franklin Institute.]

An inspection of the relative efficiencies of air and steam, that is to say, of the proportions of the whole heat entering those working fluids, which, under given practical conditions as to temperatures, pressures, etc., can be converted into mechanical work, shows an advantage in the use of air. This is connected with the difference between a fluid, which as employed undergoes change of state from the liquid to the gaseous form, and permanent gases. It is true, as will be further on more fully shown, that it is theoretically possible with the same range of temperature, to obtain the same maximum efficiency whatever be the working fluid, but practically the conditions required to reach this maximum are much more difficult to attain in steam than in air. The steam engine however possesses, so many general advantages over the air engine, such as compactness for a given power, and durability on account of the moderate temperature of the steam, even where high pressures are used, that it will probably never be more than supplemented by any other prime mover.

As each of the fluids in these two cases, seems to have its special advantages, the question of some economic combination of the two was naturally suggested, and has been to a limited degree realized within the past few years. An increased efficiency in steam engines is said to have been attained by the injection into the boiler of a small amount of air previously passed through a heater, after the plan of Mr. Warsop, or of a portion of the products of combustion, properly freed from ash.

This subject of the use of air and steam in mixture, in the so-called "*Aero-Steam Engine*," was discussed by the late Professor Rankine in a short article republished in "Van Nostrand's *Eclectic Engineering Magazine*," for February, 1873, from a preceding number of "*The Engineer*," and entitled, "Remarks on the Theory of Air and Steam Engines."

Upon reading it about a year ago, the idea occurred to the writer, of the possibility of enclosing in a boiler, a furnace with fuel undergoing combustion under pressure, as in ordinary "Furnace Gas Engines" like Roper's or Shaw's, and of employing the joint products of combustion and steam for the working fluid, thus utilizing the whole of the heat from the fuel by saving the considerable portion which in common steam boilers is lost up the chimney, in addition to obtaining a further increase in efficiency from the air according to the statement already given.

In such a case the hot gases would first meet with the water after its formation into steam by the boiler proper. Carrying out the idea farther, the plan was suggested of injecting the hot products of combustion directly into the water, so that if desirable a still greater portion of the heat might enter the steam. This would bear some analogy to the process of injecting air into the molten metal in making Bessemer steel, and to the method of boiling water by the direct injection of steam.

Upon reference however to authorities, this idea was found not to be a new one. A patent dated in 1871, was taken out in England by a Mr. Adams, for a boiler embracing the fundamental points. It is nevertheless very elementary in form and does not seem to have its parts proportioned to their uses, as may be seen upon an examination of the drawing as given in Burgh's recent "Treatise on Boilers." Mr. Burgh has evidently expressed his convictions without looking very deeply into the theory of engines used with such a class of boilers, as he concludes his description by saying: "We here add that natural laws are entirely at variance with the above theory, and therefore have no hesitation in saying that all the steam generated in that boiler would be required for the blowing engine; consequently, the motive power is entirely absorbed in the 'working' of the boiler only."

The only other boiler of the kind to be found, was described in another part of the same work, having been patented in 1869 by Mr. Fox, an Englishman. It is a locomotive boiler to be used with liquid fuel, the air for combustion being compressed by a donkey engine with separate steam boiler, and thence passed through the fire-box and finally injected into the water. As will be seen on inspection of the drawing in Burgh's treatise, this boiler also has many defects which indicate that it had not seen service. Two points especially striking in both of these plans, are the smallness of the pipes for transmitting the air, and the want of adequate provision for combustion under pressure and the injection of the products into the water. The volume of air necessary to furnish the fuel for boilers of the sizes represented, has been far under-estimated.

Having examined those works that would be likely to give notices of such boilers, without further success than finding the above two impracticable examples, it is probable that none others, where the whole of the products of combustion are mixed with the steam, have been patented, and is quite certain that none have come into actual use.

Mr. Warsop's plan, where only a small percentage of air is injected, and which has been practically tried with increased efficiency, is one of quite a different nature.

In making a general examination into the question of the advantageous use of aero-steam engines utilizing the whole of the products of combustion, and more especially into the feasibility of constructing boilers for such engines in a practical form, the investigation may be conducted under the following heads.

1. To determine by the principles of thermo-dynamics, the theoretical efficiency, together with those other quantities of practical importance which apply to air and steam when combined in this manner, under various conditions as to pressure and temperature, and with varying proportions of air in the mixture above that necessary for complete combustion of the fuel.

2. To examine what form of mechanism would be fixed upon for a boiler to be constructed according to this plan, after full consideration of all these quantities, and to discuss the general feasibility of the project, pointing out in detail the possible advantages and the difficulties liable to be practically met with.

It is proposed in the present article to treat the first only of these divisions, as embracing essentially a theory of aero-steam engines using the whole of the products of combustion from imprisoned fuel. The results of investigation into the last division may be published separately at some future period.

Previous to taking up the direct mathematical discussion of the subject laid out before us, it would not be out of place to make a few general remarks on the efficiency of air and steam, as used in separate engines, in order that we may be better prepared to infer the results which would occur upon their being used in mixture.

The efficiency of the fluid of a heat engine is defined to be the ratio of the mechanical energy exerted by a given mass of the fluid in the engine, to the mechanical equivalent of the total heat supplied the same from the external source of heat. In order to realize the greatest possible efficiency of the fluid in any heat engine, which when working between given limits of absolute temperature T_1 and T_2, is known to have the value

$$\frac{T_1 - T_2}{T_1}$$

or the ratio of the range of temperature to the higher absolute

limit, it is necessary that the whole reception of heat occur at the upper limit, that the whole of the rejection take place at the lower one, and as a further consequence, that the elevation of temperature between the two limits be produced by the expenditure of a sufficient quantity of mechanical work, which same amount is given out again in expansion while the working substance having received its supply of heat is falling in temperature to the lower limit. This maximum efficiency which was first demonstrated to exist by Carnot, is called by Professor Rankine, that of elementary heat engines. The difficulties arising in completely fulfilling the conditions of elementary heat engines have not been overcome in any of those engines so far constructed. The degree of approach to their practical fulfillment, varies considerably with the class to which the working fluid belongs.

Among the several kinds of air or gas engines where the fluid very nearly obeys the laws of a perfect gas, this maximum efficiency may in certain cases be theoretically reached, as in the perfect air engine of Carnot, and in Ericsson's and Sterling's engines, by the use of the regenerator as described in Rankine's treatise, but the difficulties to be encountered in the transmission of heat through the cylinder walls or through a heater at high temperatures, have thus far effectually prevented either of these engines from coming into extensive use.

In another proposed by Joule, the greatest theoretical efficiency is somewhat lessened on account of the exhaust necessarily taking place at a higher temperature than the induction at the compressing pump, but certain practical advantages are obtained which have already pushed it far more into use than any of the others just mentioned. As originally projected, this engine has never been constructed, but by a little inspection it will be seen that all of the modern furnace gas-engines such as those of Roper and Shaw, as well as Brayton's gas-engine, embody Joule's fundamental plan, viz:

First compressing the working fluid according to an adiabatic curve to an intermediate temperature, dependant upon the ratio of compression and lying between that of the external air and the highest chosen limit, then supplying heat from the fuel to further elevate it to the upper limit, expanding with constant pressure to a point of cut-off, then carrying out the expansion without gain or loss of heat to atmospheric pressure, and finally exhausting at a constant lower limit of temperature,

which, owing to the compression not having been carried on to the

upper limit and the whole of the additional heat there supplied, is higher, than in the case of the "perfect engine." The formula for efficiency remains the same as for elementary heat engines, being

$$\frac{T_1 - T_2}{T_1}$$

but owing to the greater elevation of the exhaust temperature T_2, its value is reduced for the same initial temperature T_1 before expansion. The cycle of operations undergone in Joule's engine is thus fully described as being applicable to the air part of an aero-steam engine worked upon the plan here to be discussed.

The efficiency of an engine using saturated steam and expanding without gain or loss of heat would be that of an elementary heat engine were it not that a portion of the available heat supplied to the steam is wasted, so to speak, in elevating the feed water to the upper limit of temperature, the boiling point of water under the given pressure. It has been pointed out that this waste might be avoided in a condensing engine by suddenly preventing further abstraction of heat by the condenser at such a point in the return stroke that the heat due to the work of compression for the remainder of the stroke, may, while at the same time condensing the residual steam, elevate its temperature to that of the water in the boiler; the whole of the elevation will thus be produced by work of compression, and (for the same heat furnished to the steam) the work developed by expansion will be increased not only by an amount equivalent to this loss by compression, but by an additional quantity due to the increased efficiency of the engine as a whole. This mode of attaining the greatest theoretical efficiency is of course known to be entirely impracticable, but in the article "Remarks on the Theory of Air and Steam Engines" before referred to, Rankine proposes to produce an equivalent effect by making use of an excess of the heat of compression of air. The air would have to be in such quantity for the whole heat developed by its compression from the atmospheric pressure to that within the boiler, as to be sufficient for heating up the feed water to the boiling point without cooling down the air below the same temperature.

In the case of superheated steam, there is, as might be expected, an increased efficiency over saturated steam at the same pressure. But this increase by no means corresponds with that of the theoretical maxi-

mum efficiency as calculated from the limiting temperatures even when an allowance has been made for not heating up the feed water by mechanical means. Thus there is given in Rankine's treatise on the steam engine, an example of a condensing engine, where under an absolute boiler pressure of 34 lbs per square inch, corresponding to a boiling point of 257·5° Fahrenheit, the efficiency of the steam when used in the saturated state was 0·128, and when further superheated up to 428° was 0·145, being greater than the previous value only in the ratio of 1·18 to 1, whereas, according to calculations based merely on the range of temperature as for elementary heat engines, the ratio of increase should be between 2 and 3, the temperature of condensation remaining the same. The cause of the comparative smallness in this departure from the efficiency of saturated steam, even when superheating is carried on to double or treble the actual range of temperature, seems to be that when the heat being supplied to any engine has once fallen in grade to any fixed lower temperature, it is impossible to get a theoretical maximum efficiency for this heat, corresponding to an upper limit higher than this temperature. In the present case of superheated steam, the great mass of the heat supplied is used in evaporating the water, and consequently can not have a maximum efficiency greater than that due to a range between the boiling point and the temperature of condensation, while only the remaining small fraction of heat used in superheating can really be considered in connection with the excess of temperature above the boiling point. This explanation would thus, in a general way, account for the comparatively slow increase in efficiency of superheated steam with temperature added in superheating, and it shows furthermore that for the same highest limit of temperature, steam will become more efficient in proportion as it is less superheated by increasing the pressure and so elevating the boiling point. These remarks will afterwards be made use of in explaining the increase of efficiency with pressure in the case of aero-steam engines.

In taking up the subject proper of this essay, the question primarily to be considered, is to what extent air can be mixed with steam and the steam in the combined fluid efficiently condensed, or more particularly whether a boiler injecting into the steam such a proportion of air as the whole of the products of combustion, can be used with a condensing engine.

The size of the lifting air-pump will of course have to be increased

in the direct ratio of the quantity of air introduced, and its volume must be that of the air to be ejected at the diminished pressure and temperature of the condenser. Where the proportion of steam largely exceeds that of the air, as in Warsop's plan, it is very probable that as far as the air-pump is concerned, a condensing engine could be employed, but in the present case although the resistance of the pump might be fully compensated by the increased efficiency, its volume would have to be so far increased as to render its use impracticable. This may be inferred from the results obtained by calculation in one of the subsequent examples, where although the least amount of air necessary for complete combustion was used, the condenser air-pump when single-acting would have to be 2·7 times, or when double-acting 1·35 times the volume of the main double-acting aero-steam cylinder. The latter itself has to be made larger than if the steam alone were yielding the same power, by a volume about equal to that of the compressing pump for the boiler. There is also another element to be considered, which although advantageous for efficient expansion in unjacketed cylinders, may put a stop to the use of condensation, even when but a comparatively small quantity of air is in mixture; and this is the retardation which the air offers to the transfer or rush of steam to the condensing surfaces.

These two serious objections of size of pump and non-efficiency of condenser indicate that it would be here impracticable to make use of condensation, and on this account the calculations and formulæ will only refer to non-condensing engines.

It might be here mentioned, that in such engines although the expansion is not carried out beyond the atmospheric pressure, owing to the tension of the steam being but a fraction of that of the working mixture, the temperature of exhaust may be carried considerably below 212° before condensation occurs, and the increased efficiency which a condenser commonly obtains by lowering the temperature of rejecting heat below that same point, thus partially realized. It might be wholly realized were the air in sufficient excess.

The case to be discussed is thus restricted to that of a high-pressure aero-steam boiler and engine of the following general description:

The boiler would be provided with an enclosed furnace, from which the whole products of combustion under pressure, would be injected into the water and there so lowered in temperature at the expense of further formation of steam, that when thoroughly mixed with all of

the steam formed, a given final temperature of super-heating would be produced.

The engine would consist essentially of a main working cylinder using this mixture expansively to atmospheric pressure, an air compressing pump to supply the imprisoned fuel at the boiler pressure, and of the mechanism by which the two would be connected and the excess of work delivered.

To be continued.

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from vol. lxvii., page 401.]

Penciling is the first and the most important operation in drafting; it requires more skill to produce neat pencil work than to "ink in" the lines after the penciling is done.

The beginner, unless he exercises the greatest care in penciling a drawing, will have the disappointment to find the paper soon becoming dirty from plumbago, and the pencil lines crossing each other at all angles, so as to give the whole a slovenly appearance.

He will also, unless he stops to consider the nature of the operation in which he is engaged, make the mistake of regarding the pencil work as a preliminary part, instead of constituting, as it does, the main drawing, and will thereby neglect that accuracy which alone can make either a good looking or a valuable drawing.

The pencil work is indeed the main operation, the inking being merely to give distinctness and permanency to the lines. The main thing in penciling is accuracy of dimensions and stopping the lines where they should terminate, without crossing others.

The best pencils only are suitable for drafting; if the plumbago is not of the best quality, the points require to be continually sharpened, and the pencil is worn away at a rate that more than makes

up the difference in cost between fine and cheap pencils, to say nothing of the effect upon the drawing.

It is common to use a flat point for drafting pencils, but a round one will be found quite as good if the pencils are fine, and quite a convenience is gained by a round point for free hand use in making short rounds and fillets.

A pencil by Faber that has detachable points, which can be set out as they are worn away, is convenient for drafting.

For compasses the lead points should be cylindrical, and fit into a metal sheath without paper packing or other contrivance to hold them, and if an apprentice has instruments that are not arranged in this manner, he should have them changed at once, both for convenience and economy.

The ink used in drawing should always be the best that can be procured; without good ink the draftsman is continually annoyed by the imperfect working of pens, and the washing of the lines if there is shading to be done.

The quality of ink can only be determined by experiment; the perfume that it contains, or tin foil wrappers and Chinese labels, are no indication of quality; not even the price, unless it be with some first-class house.

To prepare the ink, I can recommend no better plan of learning than to ask some one who understands the matter. It is better to waste a little time in grinding than to be at a continual trouble with pens, which will occur if the ink is ground too rapidly or on a rough surface.

To test ink, draw lines on the margin of the sheet, note the color, how the ink flows from the pen; after the lines have dried, cross them with a wet brush. If they wash readily the ink is too soft; if they for a time resist the water and then wash tardily, the ink is good. It cannot be expected that inks soluble in water can permanently resist its action after drying; in fact, it is not desirable that drawing ink should do so, for in shading, the outlines should be blended into the tints where the latter are deep, and this can only be effected by washing.

Pens fill themselves by capillary attraction if they are first made moist by being dipped into water; they should not be put into the mouth to wet them, as there is danger of poison from fancy inks, and the habit is not a neat one.

In drawing lines keep the pen nearly vertical, leaning just enough to prevent it from catching on the paper. Beginners have a tendency to hold pens at an angle, and drag them on their side, but this will not produce clean sharp lines, nor allow the lines to be made near enough to the square blades or set squares.

In regard to the use of the T square and set squares, I can give no rules except to observe others, and experiment until convenient customs are attained. A beginner should be careful of contracting unusual habits, and, above all things, of making important discoveries as to new plans of using instruments, or that common practice is all wrong, and that it is left for him to develop the true and proper way of drawing. This is a kind of discovery which is very apt to intrude itself at the beginning of an apprentice's course in many things beside drawing, and often leads him to do and say that which he will afterwards wish to recall.

It is generally a safe rule to assume that any custom long and uniformly followed by intelligent people, is very apt to be right; and, in the absence of that experimental knowledge that alone enables us to judge, it is safe to receive such customs, at least for a time, as being correct.

Without any wish to discourage the ambition of the apprentice, which always inspires him to laudable exertion, I nevertheless think it best to caution him against innovations. The estimate formed of our abilities is very apt to be inversely as our experience, and old engineers are not nearly so confident in their deductions and plans as beginners are.

A drawing being inked-in, we come next to dimension and centre lines. The centre lines should be in red ink, and pass through all points of the drawing that have an axial centre, or where the work is similar and balanced on each side of the line. This rule is a little obscure, but will be best understood if studied in connection with a drawing, and perhaps as well remembered without further explanation.

Dimension lines should be in blue, but may be in red. How and where to put them is a great point in drafting. To know where to put dimensions must involve a knowledge of fitting and pattern-making, and cannot be explained here; make faint lines, leaving a space in their centre for figures, when long enough. Study the distribution of centre lines and dimensions over the drawing, for the double pur-

pose of giving it a good appearance and to avoid confusion. Learn to make figures like printed numerals; they are much better understood by the workman, look more artistic, and when learned take but little if any more time than plain figures. If the scale is feet and inches, write dimensions to three feet in inches, and above this in feet and inches; this corresponds to shop custom, and is more comprehensive to the workman, however wrong it may be according to other standards.

In sketches and drawings made by the apprentice, such as are not intended for the shop, it is suggested that metrical scales be used, because such scales will not interfere with feet and inches, and it will prepare the mind for the introduction of this system of lineal measurement, which is quite sure in time to be adopted in England and America, as it has been in many other countries.

In shading drawings, be careful to put on little enough, and to put it in the right place; many will contend, and not without good reasons, that working drawings need no shading; yet it will do no harm to learn how and where they can be shaded: it is better to omit the shading from choice than from necessity. Sections must, of course, be shaded—not with lines, although I fear to attack so old a custom, yet it is certainly a tedious and useless one; sections with light ink shading of different colors, to indicate the kind of material, are easier to make and look much better. By the judicious arrangement of a drawing, a large share of it may be in section, which, in almost every case, are the best kind of view to work by. The proper coloring of these sections gives a good appearance to the drawing, and conveys the idea of an organized machine, or, to use the shop term, "it stands out from the paper." In shading sections, leave a margin of white between the tints and the lines on the upper and left-hand sides of the section; it breaks the connection and sameness, and the effect is striking; it separates the parts, and adds greatly to the clearness and general appearance of the drawing.

Cylindrical parts in the plane of sections, such as shafts and bolts, should be drawn full and have a "round shade," which, with blue tint, relieves the sameness of appearance, a point to be avoided in sectional views.

Conventional custom has assigned blue as the tint for wrought iron, neutral or pale pink for cast iron, and purple for steel. Wood is generally distinguished by "graining," which is easily done, and looks well.

The title of a drawing is a feature that has much to do with its appearance, and the impression conveyed to the mind of an observer; and, while it can add nothing to the real value, it costs so little to make plain letters, that the apprentice is urged to learn this as soon as he begins to draw, not to make fancy letters, nor indeed any kind except plain block letters, which can be rapidly laid out, and consequently used to a greater extent. By drawing six parallel lines, making five spaces, and then crossing them with equidistant lines, the points and angles in block letters are determined; and after a little practice it becomes the work of but a few minutes to put down a title or other matter on a drawing so that it can be seen at a distance, and read at a glance in searching for sheets or details.

In the manufacture of machines, there are usually so many sizes and modifications, that the drawings must assist and determine, in a large degree, the completeness in matters of classification and record. Taking the manufacture of machine tools for example: we cannot well say, each time we want to speak of them, a thirty-six inch lathe without screw and gearing, a thirty-two inch lathe with screw and gearing, a forty-inch lathe triple geared or double geared, with twenty or thirty foot bed, and so on. To avoid this it is necessary to assume symbols for machines of different classes, consisting generally of the letters of the alphabet, qualified by a single number that designates capacity and different modifications. Assuming, in the case of engine lathes, that A is the symbol for lathes of all sizes, those of different capacity and modification would be represented in the drawings and records as A^1, A^2, A^3, A^4, and so on, the letter and numerals together requiring but two characters to indicate a lathe of any kind. These symbols should be marked, in large, plain letters, on the left-hand lower corner of the sheet, so that the manager or workman or any one else can see at a glance what the drawing relates to. This symbol should run through the time-book, cost account, sales record, and be the technical name for the machines, which should always be spoken of in the works by the name of their symbol.

In making-up time a good plan is to supply each workman with a small slate and pencil, on which he enters his time as so many hours charged to the respective symbols. Instead of interfering with his time, this will increase the workman's interest in what he is doing, and naturally lead to a desire to diminish the time charged to the various symbols.

When the symbols are added to a drawing, the next thing is the "pattern numbers." These should be marked in prominent, plain figures on each piece of casting, either in red ink or other color that will contrast with the general face of the drawing. These pattern numbers, to avoid the use of symbols in connection with them, must include consecutively all patterns used in the business; these numbers can extend to thousands without inconvenience.

A book containing the pattern record should be kept by the head draftsman, in which these numbers are set down, with a short description to identify parts to which the numbers belong, so that various details can at any time be referred to. Besides this description, there should be, opposite the catalogue or pattern numbers, ruled spaces, in which to enter the weight of castings, the cost of the pattern and, if needed, the amount of turned, planed or bored surface on each piece when it is finished.

In the same book the assembled parts of each machine should be set down, in a list, with its symbol and descriptive name, so that orders for castings can be made from this list without other references.

This system is the best one known to the author, and is in substance the plan now adopted in some of the best engineering establishments. It may be susceptible of improvement; he hopes it is; but let the apprentice seize on the idea of some system at the beginning; any plan is better than none, and the schooling of the mind to be had in the observance of systematic rules is the great point in view. New plans for promoting system may at any time arise, but they cannot be at any time understood and adopted except by those who have cultivated a taste for order and regularity.

In regard to shaded elevations, it may be said that photography has superseded them for the purpose of illustrating machinery, and but few establishments care to incur the expense of ink-shaded elevations.

Ink shading cannot be done with various degrees of care, and in a longer or shorter time; there is but one standard for it, and that is that such drawings should only be made with great care and skill.

A shaded elevation, although it may surprise and please the unskilled, is execrable in the eyes of a draftsman or an engineer, unless it is a good one; and, as the making of shaded elevations can be of but little assistance to an apprentice draftsman, it is better to save the time that must be spent in order to make a good drawing and ap-

ply the same study and time to other matters of greater importance.

It is not assumed that shaded elevations should not be made, nor that ink shading should not be learned, but to insist on the greater importance of other kinds of drawing, which is too often neglected to gratify a taste for picture-making that has but little to do with mechanics.

Isometrical perspective is often useful in drawing, especially in wood structures when the material is of rectangular sections and disposed at right angles, as in machine frames. One isometrical view, which can be made nearly as quickly as a true elevation, will show all the parts, and can be figured for dimensions the same as plane views.

True perspective, although never necessary in mechanical drawing, may be studied with advantage in connection with geometry, and often lead to the explanation of problems in isometric drawing, and will also assist in free hand lines that have often to be made to show parts of machinery that are oblique to the regular planes.

This far the remarks on drafting have been confined to manipulation mainly. Unlike most branches of engineering work, drafting must as an art consist mainly in special knowledge, and is not capable of being learned or practiced upon general principles. It is therefore impossible to give the learner much aid by searching after principles, and the few propositions that follow comprehend nearly all that can be explained in words.

Geometrical drawings consist in plans, elevations and sections; plans being views on the top of the object in a horizontal plane; elevations, views on the sides of the object in vertical planes, and sections, views taken on bisecting planes, at any angle through the object.

Drawings in true elevation or in section are based upon flat planes, and give dimensions parallel to the planes in which the views are taken.

Two elevations taken at right angles to each other, fix all points, and give all dimensions of parts that have their axis parallel to the planes on which the views are taken; but when a machine is complex, or when several parts lie in the same plane, three and sometimes four views are required to display all the parts in a comprehensive manner.

Mechanical drawings should be made with reference to all the processes that are required in the construction of the work, and the

drawings should be responsible, not only for dimensions, but for unnecessary expense in forging, fitting, pattern-making, and moulding.

Every "piece" that is laid down has something to govern it that we will term a "base," some condition of functions or position that, if understood, will suggest its size, shape, and relation to other parts. By searching after a "base" for each and everything, we proceed upon principles, avoid error, and continually maintain a test of what is done. Every wheel, shaft, screw or piece of framing should be made with a clear view of the functions it has to fill, and there are always reasons why such parts should be of a certain size, have such a speed of movement, or a certain amount of bearing surface. These reasons or conditions may be classed as *expedient*, *important*, or *essential*.

I now come to note a matter in connection with drafting to which the attention of the apprentice is earnestly called, and which if he neglects, all else may be useless. I allude to indigestion, and its resultant evils induced by drafting. All sedentary pursuits give rise to this trouble, but none of them can compare with drafting, where every condition in the way of promoting this derangement exists.

In drafting, the muscles are at rest, circulation is slow, the mind is intensely occupied, robbing the stomach of its blood and vitality, and worse than all, the mechanical action of the stomach is arrested by leaning over the edge of the drafting board. I regret my inability to give any fixed rule to avoid this danger, but am at the same time confident that any apprentice who understands the danger can avert it by applying some of the logic which has been reconmended in the study of mechanics. We can conclude that if anything tends to induce indigestion, its opposite tends the other way, and will arrest it; if stooping over the drafting-board interferes with the action of the digestive organs, leaning back does the opposite; therefore keep your doard as high as possible, stand at your work, and cultivate a constant habit of straightening up and throwing your shoulders back; if possible, take brief intervals of vigorous exercise.

Like rating the horse-power of a steam engine, by multiplying the force into the velocity, we must estimate the capacity of a man by multiplying his mental acquirements into his vitality. Latent power is of no use, neither is latent knowledge or skill.

Physical strength, bone and muscle, must be one of the elements in successful engineering experience, and a store of these things must be

laid in at the same time with a mechanical education, or it will be found that when ready to enter upon a course of practice, that most important element, the propelling power, has been omitted.

Pattern Making and Casting.

Patterns and castings are so intimately connected that it would be difficult to treat of each without continually confounding them together; it is therefore proposed to combine patterns and moulding under one head. Every operation in the pattern shop has reference to some operation in the foundry, and patterns considered separately from moulding operations would be incomprehensible to any but the skilled.

Next to designing and drafting, pattern making is the most intellectual of what has been termed engineering processes—the department that must include the exercise of the greatest amount of personal judgment on the part of the workmen, and at the same time demands a high grade of hand skill.

In every other department there are drawings furnished, and the plans of the work are dictated by the engineering department of machinery-building establishments, but the pattern-maker makes his own plans for constructing patterns, and has even to reproduce the drawings of the fitting shop to work from. Nearly everything pertaining to patterns is left to be decided by the pattern-maker, who from the same drawings and through the exercise of his judgment alone, makes patterns that are durable and expensive, or temporary and cheap, as the probable extent of their use may determine.

The expense of patterns should be divided among and charged to the machines for which the patterns are used, but there can be no constant rules for assessing or dividing this cost. A pattern may be used but once, or it may be used for years; it is continually liable to be superseded by changes and improvements that cannot be predicted before hand; and in making patterns the question of how much ought to be expended on them continually arises—a matter that should be mutually determined by the engineer and the pattern-maker, but is generally left to the pattern-maker alone, for the reason that but very few mechanical engineers study and learn pattern-making so well as to dictate the construction of patterns.

To point out to the apprentice some of the leading points or conditions to be taken into account in pattern-making and which must be

understood in order to manage this department, I will refer to them in consecutive order.

First.—Durability, plans of construction and cost, which all amount to the same thing. To determine this point, there is to be considered the amount of use that the patterns are likely to serve, whether they are for standard or special machines, and the quality of the castings so far as affected by the patterns. A first-class pattern framed to withstand moisture and rapping, may cost twice as much as another that has the same outline; yet the cheaper pattern may answer almost as well to form a few moulds as the expensive one

Second.—The cast and manner of moulding is determined by the patterns, which may be parted so as to be 'rammed up' on fallow boards or a level floor, or the patterns may be solid and have to be bedded, as it is termed; pieces on the top may be made loose, or fastened on so as to 'cope off;' patterns may be well finished so as to draw clean, or rough so that the mould will require a great deal of time to finish after the pattern is removed.

Third.—The soundness of such parts as are to be planed, bored and turned in finishing; this is also a matter that is determined mainly by how the patterns are arranged, by which is the top and which the drag, or bottom side as determined by the manner of drawing, and the provisions for avoiding dirt and slag.

Fourth.—Cores where used, how vented, how supported in the mould, and I will add how made, because cores that are of an irregular form are often more expensive than the external moulds, including the patterns. The cost of patterns is often greatly reduced and sometimes increased, by the use of cores, which may be used either to cheapen patterns, add to their durability, or to insure soundness in the castings.

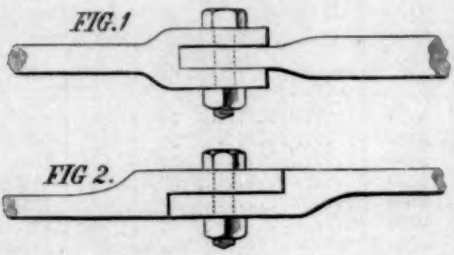
To be continued.

ON THE STRENGTH OF MATERIALS.

By Chief Engineer Wm. H. Shock, U. S. Navy.

In designing some boilers for high steam, I was anxious to obtain the necessary strength with a minimum amount of metal, economy of weight being a necessary, if not an absolute condition, and having no reliable data at hand from which to ascertain the "detrusive strength" or resistance to shearing of certain size bolts, I instituted a series of

very carefully conducted experiments on bolts of various dimensions, under the two possible conditions in which they might be used in connection with the bracing of boilers, and for other purposes; i. e., when used as shown in fig. 1, double cut, or as in fig. 2, single cut.



The bolts, sixty in number, (twelve each of the following shop dimensions, viz., 1, $\frac{7}{8}$, $\frac{3}{4}$, $\frac{5}{8}$ and $\frac{1}{2}$ inch diameters) were forged in the usual manner without any reference whatever to the experimental tests to be made. The material used was the ordinary bar-iron of commerce, my great wish being to obtain the data sought for, under conditions of actual practice.

When the bolts were received in the experimenting room, they were carefully measured with "vernier calipers," numbered, and drawings made of them with dimensions marked on.

The testing machine used belonged to the Ordnance Department at the Navy Yard, Washington, and is an instrument of very delicate adjustment.

The barometrical, as well as the thermometrical conditions, were uniform during the experiments.

The attachments (see plate I—figs. *a*,*a*—*b*,*b*—*c*,*c*—and *d*) were hardened, the inner angles of the holes being slightly rounded, or counter-sunk, to avoid the otherwise "knife edge" being brought to bear on the bolts, thus bringing the experimental specimens under conditions approximating actual practice.

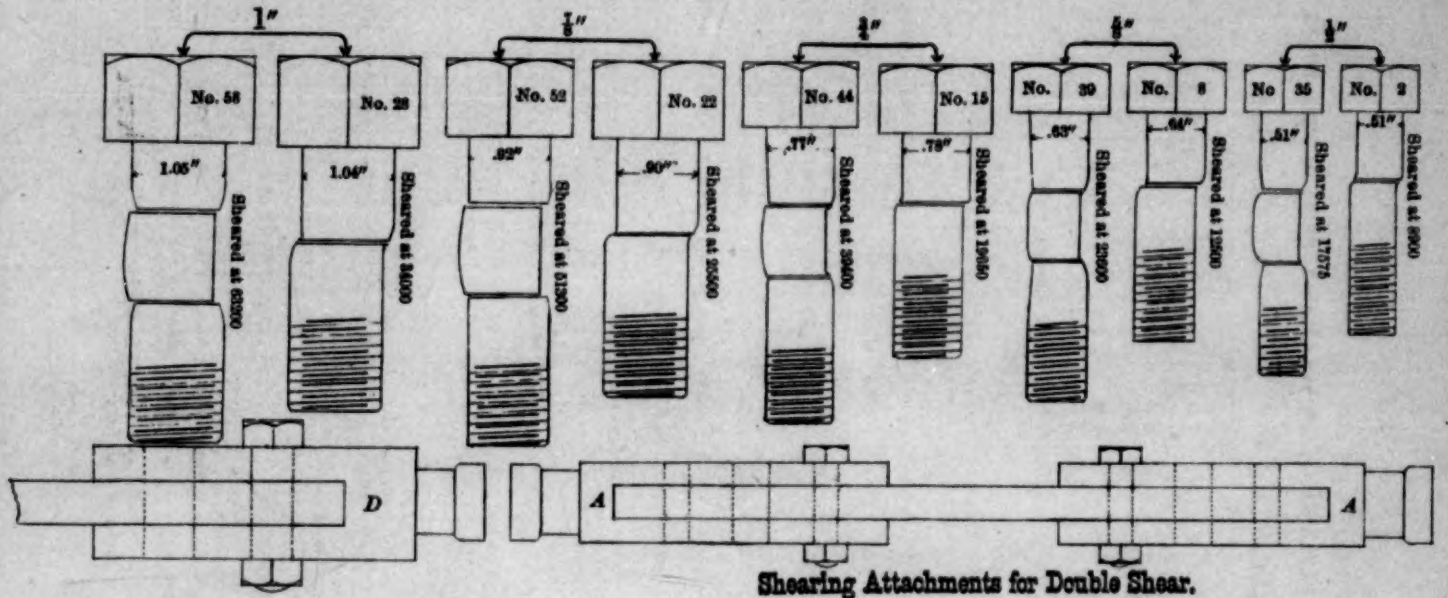
The character of the fracture in the several specimens was singularly uniform; those shown in plate I being correct exponents of the rest.

The following tabular statement shows the results obtained:

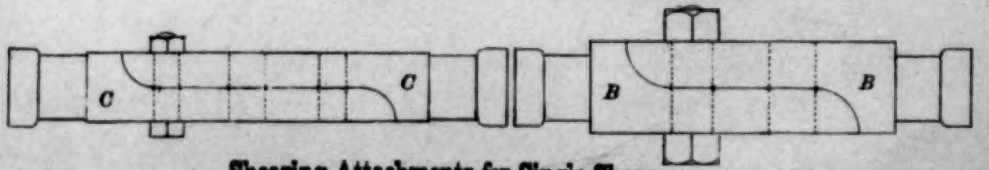
RESULTS OF EXPERIMENTS ON SHEARING STRAINS OF IRON BOLTS.

SINGLE SHEAR.					DOUBLE SHEAR.				
Number of Exp.	Actual Diameter of Bolt.	Actual Shearing Strain.	Area of Mean Section.	Shearing Strain per Square inch of Section.	Number of Exp.	Actual Diameter of Bolt.	Actual Shearing Strain.	Area of Mean Section.	Shearing Strain per Square inch of Section.
	inches.	lbs.	sq. ins.	lbs.		inches.	lbs.	sq. in.	lbs.
1	·51	9000	.....	.....	31	·51	16175	.....	.....
2	·51	8900	.....	.....	32	·51	16800	.....	.....
3	·52	9400	.....	.....	33	·50	16050	.....	.....
4	·52	9400	.....	.....	34	·52	16400	.....	.....
5	·52	9400	.....	.....	35	·51	17575	.....	.....
6	·51	9000	.....	.....	36	·51	17600	.....	.....
Mean	·515	9183·3	·20831	44085	Mean	·51	16766·6	·40856	41036
7	·64	12900	.....	.....	37	·65	25650	.....	.....
8	·64	12500	.....	.....	38	·63	23700	.....	.....
9	·64	13300	.....	.....	39	·63	23600	.....	.....
10	·66	12750	.....	.....	40	·63	24800	.....	.....
11	·65	12650	.....	.....	41	·63	24600	.....	.....
12	·65	12750	.....	.....	42	·64	24300	.....	.....
Mean	·6466	12808·3	·32837	39006	Mean	·635	24442	·63338	38589
13	·78	18800	.....	.....	43	·78	36650	.....	.....
14	·78	19500	.....	.....	44	·77	39400	.....	.....
15	·78	19650	.....	.....	45	·78	37700	.....	.....
16	·79	18800	.....	.....	46	·76	36400	.....	.....
17	·78	19000	.....	.....	47	·78	36650	.....	.....
18	·79	18400	.....	.....	48	·79	39400	.....	.....
Mean	·7833	19025	·48192	39477	Mean	·7766	37700	·94751	39789
19	·91	27600	.....	.....	49	·91	51600	.....	.....
20	·90	26600	.....	.....	50	·92	47650	.....	.....
21	·89	26550	.....	.....	51	·93	46200	.....	.....
22	·90	25500	.....	.....	52	·92	51300	.....	.....
23	·91	26425	.....	.....	53	·91	52000	.....	.....
24	·91	26700	.....	.....	54	·91	51375	.....	.....
Mean	·9033	26562·5	·64089	41446	Mean	·9166	50021	1.31988	37822
25	1·03	33000	.....	.....	55	1·03	64000	.....	.....
26	1.04	34800	.....	.....	56	1·03	61700	.....	.....
27	1·04	35650	.....	.....	57	1·04	63550	.....	.....
28	1 04	34000	.....	.....	58	1·05	63200	.....	.....
29	1·04	35800	.....	.....	59	1·03	63525	.....	.....
30	1·03	32900	.....	.....	60	1·03	63500	.....	.....
Mean	1·036	34358·3	.84395	40071	Mean	1·035	63246	1.68268	37586
Mean of the above				40817	Mean of the above				38984

Mean of both Sets $\frac{40817+38984}{2} = 39900$



Shearing Attachments for Double Shear.



Shearing Attachments for Single Shear.

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Chemistry, Physics, Technology, etc.

EXPERIMENTS ON THE TENACITY OF MALLEABLE METALS AT VARIOUS TEMPERATURES.

By M. A. BAUDRIMONT.

[*Translated from the Annales de Chimie et de Physique, Series* III, *Vol.* xxx, *page* 304, 1850, *by Chief Engineer, B. F. Isherwood, U. S. N.*]

TO THE EDITOR OF THE JOURNAL OF THE FRANKLIN INSTITUTE:—

DEAR SIR: The following memoir on the tensile strength of the principal malleable metals at different temperatures, addressed by its author to the Academy of Sciences at Paris, seemed to me to contain so much both curious and useful in engineering, that I have translated it for the JOURNAL, as it has never before appeared in English. The results with iron in particular are very singular in many respects, proving that metal to be an exception within certain limits—and the only one so far as known—to the general law of decreasing tenacity in function of increasing temperature.

The ingenious experimenter has omitted to state whether he experimented on the same piece of iron wire at the different temperatures, or on different pieces; and, if the former, whether he experimented first at the lower and afterward at the higher temperatures, or the reverse; for, if he experimented with the same piece of wire, and at the lower temperatures first, as was probably the case, the results are not quite conclusive, as will appear from the following considerations:

That no piece of iron wire has precisely the same tenacity at every point of its length, is absolutely certain; consequently, there must be a weakest point, a next weakest, and so on. Now when the wire is first stretched to rupture, it will yield at the weakest point, showing a certain tenacity. If it be thus stretched again it will yield at the next weakest point, showing a greater tenacity than the previous one, and so on, showing for each successive stretching an increased tenacity. If the first stretching takes place at the lower temperature and the next at the higher one, the difference in the two tenacities shown, is attributed to the difference of temperature, whereas it may be due to the fact that the wire at the point of rupture in the second case, had, for equal temperatures, a considerably greater tenacity than at the point of rupture in the first case. What is really shown by such experiments, is the difference of the tenacities at the two points of successive rupture with equal

temperatures, modified by the influence of the different experimental temperatures.

The experiments made on the tensile strength of wrought iron in 1837 by a Committee of the Franklin Institute, had first shown the anomalous fact of its increase with the increase of temperature between certain limits of the latter. And, in 1853, Mr. Fairbairn published his experiments, demonstrating the same truth. These, together with the experiments made by Baudrimont in 1843, and detailed in the following memoir, constitute all the knowledge we possess on the subject.

In the experiments by the Committee of the Franklin Institute, however, the same piece of iron was successively ruptured, and gave, as a general result just what might have been expected, namely, increasing tenacity at each rupture under ordinary atmospheric temperatures; but the Committee failed to detect the reason, and left the naked fact standing in their tables without explanation. The experiments made by the Committee under high temperatures, were vitiated by the same cause, as they were made on the same piece of iron after it had been broken—often several times—under low temperatures. The Committee did not perceive that the greater tenacity of the iron observed under the high temperature might be due to the fact that the iron was then necessarily fractured at a stronger point than under the preceding low temperatures; but they compared, in all cases, the tensile strength obtained from the first trial under low temperatures, with the tensile strength obtained under the high temperature often after several fractures had been made under the low temperature and the weakest points thereby eliminated. The tenacity thus found under the high temperature, was of course, as much too great, comparatively, as the tenacity under the low temperature, for the number of fractures made, exceeded the tenacity at the first fracture under the low temperature. Yet, obvious as is this deduction, the Committee ignored it and attributed the entire increase of tenacity shown under the high temperature to the influence of that temperature alone, while, in fact, this increase was mainly, if not wholly, due to the elimination of the weakest points by the several previous fractures of the iron made under low temperatures.

As far as I am aware, this fact of the necessarily increasing tenacity of the iron at successive fractures as a consequence of the continued elimination of weaker points by each preceding fracture, is now pointed out by me for the first time. The failure to perceive it, caused Professor Walter R. Johnson to attribute an actual increase of strength

conferred on the iron by the simple process of stretching, whereas this result was solely due to the removal of weak points. Combining this error with that of the increase of strength assumed to be due to high temperatures, but really due to the same cause, led him to propose what he termed the "thermo-tension" treatment of iron as a means of increasing its tenacity. The whole principle of his process, however, being based on fallacious assumptions, its practical application proved worthless.

The conditions under which the experiments of Mr. Fairbairn were made, and particularly the fewness of their number, do not, in my opinion, justify any positive conclusions.

From a careful comparison of all the experiments I have been able to collect concerning the influence of temperature on the tenacity of wrought iron, there results that, between the temperatures of zero and 550 degrees Fahrenheit, this influence is exactly null, developing the important practical fact that, between these limits, no provision need be made by the engineer for effect of differences of temperature.

B. F. ISHERWOOD,
Chief Engineer, United States Navy.

About sixteen years ago, I conceived an idea that the laws of the cohesion of homogeneous substances, that is to say those laws which control the reciprocal action of their molecules, might be ascertained experimentally. The idea could not be immediately realized in consequence—as always happens in opening a new road—of the numerous obstacles to be in turn surmounted before advancing farther. In order, therefore, to overcome the difficulties that opposed the accomplishment of my project, I made a programme of the indispensable preparatory researches requiring completion before an approach could be even commenced toward my principal object which included the investigation of the constitution of wire-drawn metals, and of their elasticity and tenacity. In 1835, I had the honor to communicate to the Academy the researches on the constitution of wire-drawn metals, which have been inserted in the "*Annales de Chimie et de Physique*," 2d series, tome lx.

There resulted from these first researches, that metals acquire permanent properties only after careful annealing, and that the different methods of working them, such as hammering, rolling and wire-drawing, by causing notable changes in their volume, produce, at the same time, considerable modifications in their tenacity.

In April, 1837, I undertook experiments on the elasticity of metals. They were made by the method of stretching, for copper, iron, silver, platinum, gold, lead and tin. I found from those experiments, conducted by a process easy and exact to put in practice, that the lengthening of wire-drawn metals was proportional to the weights applied up to the instant of rupture; a result which M. Wertheim has since obtained from a series of observations not less numerous and not less positive.

I have not been able to publish these experiments because, in a theft committed at my house, the instrument used for measuring the relative diameters of the wires was stolen, and unfortunately I did not know its unit. Nevertheless, I had obtained sufficient results for the object proposed, and for even still more.

It was only in 1843 that I could undertake the third set of experiments, the one relative to the tenacity of the metals and which is the subject of the present memoir. Since that date, M. Wertheim has published the results of researches analogous to mine, but as he did not experiment at the temperature of 32 degrees Fahrenheit, and has left omissions in relation to copper and palladium, besides not having operated by the same process, I believe I ought to submit them to the judgment of the Academy.

The metals experimented on were copper, gold, platinum, silver, palladium and iron. They were drawn into wire, and all, with the exception of the iron, made to pass through the same hole. The iron wire was smaller, because otherwise it would have required too great a weight to fracture it.

I operated successfully at 32 degrees Fahrenheit in melting ice, at 212 degrees Fahrenheit in boiling water, and at 392 degrees Fahrenheit in an oil-bath heated very slowly, the temperature of which was measured by a mercurial thermometer.

The wires had been annealed with a great deal of care, and were placed horizontally in a cast-iron vessel containing the liquid forming the bath. This vessel was suspended by weights attached to chains passing over pullies, which allowed it to be raised or lowered at will for conveniently arranging the wires within it. The furnace for heating the liquid when operating at the high temperatures, was mounted on a wheeled frame-work so that it could be instantly run on one side in order to lower the vessel.

The wires being small in diameter, and good conductors of heat, would evidently quickly acquire the temperature of the bath, and re-

main constantly at it notwithstanding the heat developed by the stretching to which they were subjected. One of their extremities was fixed immovably to an iron support; and the other, by means of a light strong chain guided by three pullies, was attached to a zinc receiving-pan, into which dry sand was arranged to run from a box containing it, with a velocity controllable at will by a more or less inclination of the box. When the wire was ruptured, the zinc pan, in falling, struck a handle which closed a valve that instantly arrested the flow of sand. The zinc pan and the sand it contained, were then weighed on a well-made, strong, and very sensitive balance.

The diameter of the wires was measured at the temperature of 60·8° Fahrenheit by callipers sensitive to the $\frac{1}{2540}$ of an inch.

The direct results of the experiments are given in the following tables:

Diameter of the Wires at 60·8° *Fahrenheit.*

Copper - - - -	0·017 716 860 inch.
Gold - - - - -	0·016 240 455 "
Platinum - - - -	0·016 142 028 "
Silver - - - - -	0·015 679 421 "
Palladium - - - -	0·015 649 893 "
Iron - - - -	0·006 889 890 "

Experiments on the Tenacity of Wire-Drawn Metals at 32° *Fahrenheit.*

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds, producing rupture of the Wire.	Mean of the Weights.
Copper,.....	6·38 9·10	10·108 720 000 9·921 317 333	10·015 018 666
Gold,.....	2·37 2·24 2·36	5·613 260 877 5·150 266 067 5·500 819 280	5·421 448 741
Platinum,.....	2·20 2 40	6·468 698 905 6 702 401 047	6·585 549 976
Silver,.....	2·39 2·26 2·32	7·859 888 070 7·760 674 896 7·716 580 153	7·779 047 706
Palladium,.....	3·29 3·19	10·119 743 686 9·844 151 538	9·981 947 612
Iron,.....	3·40 3·53 4·30 3.44	10·975 181 714 11·125 103 843 10·847 306 957 10·598 171 655	10·886 441 042

Experiments on the Tenacity of Wire-Drawn Metals at 213° Fahrenheit.

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds, producing rupture of the wire.	Mean of the Weights.
Copper,	2·56	8·768 239 797	8·725 798 601
	3·90	8·666 821 880	
	2·55	8·796 901 374	
	2·57	8·671 231 354	
Gold,	2·11	4·528 530 181	4·487 375 087
	2·11	4·645 381 252	
	3·47	4·288 213 828	
Platinum,	3·28	5·280 345 562	5·613 260 877
	1·36	5·943 971 454	
	1·35	5·615 465 614	
Silver,	1·51	6·149 012 013	6·388 777 182
	2·40	6·735 472 104	
	1·53	6·395 942 578	
	2·29	6·274 682 033	
Palladium,	3·35	9·001 941 932	8·888 397 967
	3·60	8·774 854 002	
Iron,	3·35	10·099 901 051	10·165 491 982
	3·25	10·066 829 993	
	4·12	9·835 332 589	
	3·46	10·659 904 297	

Experiments on the Tenacity of Wire-Drawn Metals at 392° Fahrenheit.

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds, producing rupture of the Wire.	Mean of the Weights.
Copper,	4·54	7·302 089 561	7·267 916 135
	3·28	6·673 739 463	
	4·80	7·915 006 500	
	3·13	7·180 829 016	
Gold,	0·45	3·737 029 531	3·797 659 803
	0·46	3·858 290 076	
Platinum,	1·30	4·814 705 067	5·030 328 291
	1·17	5·002 548 676	
	1·19	5·273 731 130	
Silver,	1·10	5·134 832 974	5·102 864 252
	1·50	5·070 895 529	
Palladium,	1·34	6·581 140 502	7·407 916 947
	1·54	7·650 438 037	
	1·58	7·992 172 301	
Iron,	3·10	11·310 301 767	11·149 355 950
	3·10	11·237 545 433	
	3·20	10·900 220 650	

Although the experiments recorded in the preceding tables were made under very favorable conditions for uniformity, it is none the less true that they present considerable differences in the results; nevertheless, these differences are within such limits as to show with precision that the tenacity of the metals varies with the temperature to which they are subjected, and according to determinable laws.

In a theoretical point of view, the maximum tenacity obtained should be the nearest to the truth, for in the experiments there was nothing to increase the cohesion of the molecules of the metals, while on the contrary, many circumstances might diminish it; but in a practical point of view, the mean result must be adopted, for it has more chances to be correct in application.

The following table has been constructed according to this principle; and it contains, additionally, the tenacity of the metals on which I operated calculated for one square inch of cross section. This calculation permits, further, the comparison of the tenacities of the different metals with each other. [See page 44.]

There results from these experiments:

1. That the tenacity of each metal varies with the temperature.
2. That, generally, it decreases—but not without exception—as the temperature rises.
3. That for silver, it diminishes more rapidly than the temperature rises.
4. That for copper, gold, platinum and palladium, it diminishes less rapidly than the temperature rises.
5. That iron presents a particular case and a very remarkable one. At 212° Fahrenheit, its tenacity is less than at 32° Fahrenheit, but at 392° Fahrenheit it is greater than at 32°. M. Wertheim has likewise obtained an analogous result. The experiments, furthermore, have been repeated a sufficient number of times to leave no doubt in that respect.

If the tenacities be taken for ordinates, and the temperatures for abscissas, and the points thus obtained be joined by straight lines, there will appear by simple inspection of this graphic trace that, if the tenacity of the iron ought to be represented by a symmetrical curve, the minimum of tenacity would fall a little below 212° Fahrenheit; but should the variation in the tenacity of the metal be due to a new arrangement of its molecules, causing, as a consequence, a variation in the latent heat, then, by as much as that result is probable, should the minimum of tenacity be beyond 212° Fahrenheit, and the line which represents it ought to jut up suddenly and parallel to the ordinates.

Tenacity of the principal Malleable Metals at the Temperatures of 32°, 212°, and 392° Fahrenheit, in Wire of the Diameter and Cross Section experimentally found; and for one square inch of Cross Section as given by calculation.

Name of the Metal.	Diameter of the wire in fractions of an inch, at 60·8° Fahr.	Cross section of the wire in fractions of a square inch, at 60.8 Fahr.	Tenacity in pounds at			Tenacity in pounds per square inch of cross section at			
			32° Fahr.	212° Fahr.	392° Fahr.	32° Fahr.	212° Fahr.	392° Fahr.	
Gold,	0·016 240 455	0·000 207 152	5·613 260 877	4·645 381 252	3·858 290 076	27 097	22 425	18 625	Maximum.
			5·421 448 741	4·487 375 087	3·797 659 803	26 171	21 662	18 333	Minimum.
Platinum,	0·016 142 028	0·000 204 648	6·702 401 047	5·943 971 454	5·273 731 130	32 751	29 045	25 770	Maximum.
			6·585 549 976	5·613 260 877	5·030 328 291	32 180	27 429	24 580	Minimum.
Copper,	0·017 716 860	0·000 246 522	10·108 720 000	8·796 901 374	7·915 006 500	41 005	35 684	32 107	Maximum.
			10·015 018 666	8·725 798 601	7·267 916 135	40 625	35 395	29 482	Minimum.
Silver,	0·015 679 421	0·000 193 086	7·859 888 070	6·735 472 104	5·134 832 974	40 706	34 883	26 593	Maximum.
			7·779 047 706	6·388 777 182	5·102 864 252	40 288	33 088	26 428	Minimum.
Palladium,	0 015 649 893	0·000 192 362	10·119 743 686	9·001 941 932	7·992 172 301	52 608	46 797	41 547	Maximum.
			9·981 947 612	8 888 397 967	7·407 916 947	51 891	46 206	38 510	Minimum.
Iron,	0·006 889 890	0·000 372 834	11·125 103 843	10·659 904 297	11·310 301 767	298 393	285 915	303 360	Maximum.
			10·886 441 042	10·165 491 982	11·149 355 950	291 991	272 655	299 043	Minimum.

Further experiments are indispensable for solving this problem, which is one of great interest not only in a theoretical point of view, but also because it appertains to the most commonly used metal, and the one always employed in the construction of steam boilers.

THE MOON'S FIGURE AS OBTAINED IN THE STEREOSCOPE.

By Chas. J. Wister.

In a paper published some time since, in the "*Cornhill Magazine*," and republished, September last, in the "*Living Age*," entitled "*News from the Moon*," a singular argument, and to my mind a singularly fallacious one, is put forth in confirmation of the figure of the moon as deduced from the calculations of the continental astronomer, Gussew, of Wilna. The article referred to is without signature, but as the author alludes to his correspondence with Sir John Herschel, he no doubt speaks *ex cathedra*.

The figure of the moon should be, as proved by Newton, an ellipsoid, her shortest diameter being her polar one, her longest diameter that turned towards the earth, and her third diameter lying nearly east and west, a diameter intermediate to the other two. Newton further found that her shortest diameter would not differ more than sixty-two yards from her longest—an insignificant difference surely in a body whose mean diameter is about twenty-one hundred miles.

Gussew, however, comes in at this point with an assertion based upon measurements of De la Rue's photographic copies of the moon at the extremes of her librations; and upon ocular demonstration derived from viewing these different perspectives of the moon's image combined by the aid of the stereoscope, undertakes to subvert his great predecessor's theory, and to substitute one of his own, founded on this very unreliable testimony. He asserts not only that the moon is egg-shaped, its smaller end being turned earthward, but that the point of this colossal egg rises seventy miles above the mean level of its surface. Now it is to the proof of this as derived from stereoscopic evidence that I take exception for reasons hereinafter set forth.

The stereoscopic views of the moon are, as already stated, taken in the opposite stages of her librations, in order to obtain greater differences of perspective than would be obtained if taken in the ordinary

way, where the separation of the two pictures corresponds with the average distance between the eyes of adults—four and a half inches; for this, it is evident, would give no more spheroidal appearance when viewed through stereoscopic glasses than is obtained by viewing her by unassisted vision, in which cases she appears as a disk only, and not as a sphere. With the same object—that of increasing the stereoscopic illusion (for illusion only it is) it is not uncommon for photographers, when taking stereoscopic views of distant scenery, to avail themselves of the same means—that of unnaturally increasing the base of operations—and thus effecting a much greater apparent separation of the various planes of distance than really exists. The effect of this is to distort the picture painfully, advancing the middle distance boldly into the foreground—similar points being combined by the stereoscope much nearer the eyes than if the pictures had been taken in the normal way—whilst the foreground is seen so near that one feels it in his power almost to reach it with his hand. Another and more objectionable feature of this exaggerated perspective effect is that all near objects are dwarfed; men become pigmies; imposing mansions are reduced to baby-houses, and lofty trees become insignificant bushes—the reason being that these objects, though seen at points much nearer the eye, subtend, nevertheless, the same visual angles as though seen at more distant points—points corresponding with their true position in the landscape—for the photographic representations of them are no larger, and therefore appearing nearer, and yet subtending no greater visual angles, the impression upon the mind is that of smaller objects. Every one, I think, who has viewed stereoscopic pictures of distant objects, combining middle distance and foreground, must have witnessed this distortion.

Now let us apply this principle of optics to De la Rue's exaggerated stereoscopic perspectives of the moon, and what is the result?

Sir William Herschel says, in illustration of the effect of stereoscopically combining images of our satellite taken at opposite stages of her librations, "it appears just as a giant might see it, the interval between whose eyes is equal to the distance between the place where the earth stood when one view was taken, and the place to which it would have been removed (the moon being regarded as fixed) to get the other." Now this would all be very well provided the pictures produced were for the use of giants formed after the pattern proposed; for they would see the stereoscopic image under exactly the same circumstances that they would see the moon herself in the natural way

with their widely separated organs—no greater change being required in the direction of the optic axes in combining similar points of the two perspectives than is required in viewing corresponding points of the moon's surface by unassisted vision; but when these exaggerated perspectives are presented in a stereoscope to finite beings like ourselves, the effect is magical indeed. Then do near points of the moon protrude in a most alarming manner, threatening to punch us in the eyes, the whole presenting the appearance of an unusually elongated turkey's egg. Neither the modest sixty-two yards of the immortal Newton, nor the more pretentious seventy miles of Gussew would satisfy her claims now; nothing, indeed, less than several thousand miles would represent the difference between her longest and shortest diameters thus distorted.

Indeed, for a very pretty scientific toy, with which De la Rue has supplied us, this distortion of the moon's image is of little moment. The curious are, no doubt more pleased with it than if it appeared in its true proportions—for figures generally are more admired the less nearly they conform to nature's lines—but that men of science, even great men, should accept this delusive and distorted image as a basis for serious investigation of the figure of our satellite, conscious of the manner in which pictures producing this image are taken—and, though forwarned, should not be forarmed—passeth my understanding. It is but another instance of the too great avidity with which world renowned philosophers seize upon the most unreliable evidence from which to draw conclusions most important to science, thus shaking the faith of those who have hitherto looked upon them as infallible.

ON THE MECHANICAL PROPERTIES OF MATERIALS OF CONSTRUCTION.

And on Various Previously Unobserved Phenomena, Noticed during Experimental Researches with a New Testing Machine, with Autographic Registry.

[Read before the Am. Soc. Civil Engineers, April 4, 1874.]

By Prof. R. H. Thurston.

[Continued from Vol. LXVII, page 430]

Section II.

21. The manner in which this reduction of internal strain occurs, by continued stress at the limit of elasticity, as here observed, may be readily conceived.

When the metal is thus strained, many sets of molecules are placed in positions in which they exert a maximum effect tending to produce molecular changes which may equalize the originally irregular distribution of inter-molecular stresses. After a time, the change actually takes place by "flow," and the resisting power of the piece becomes increased, and its limit of elasticity raised, simply because its forces are now no longer divided, and may act together in resisting external forces. The diagram itself exhibits the best evidence of the occurrence of flow, but it is also shown by an inspection of the broken specimen, as in Figures 6, 7 and 11, of Section I.

It was at first suspected that an action had been detected in this phenomenon, similar to that by which the "portative force" of a magnet is increased by loading its keeper more and more heavily until it becomes "supersaturated." It is not impossible, perhaps not improbable, that the two cases are similar, in some respects, this behaviour of the cohesive force in the present example, aiding to produce the extraordinary increase of resisting power here observed.

A comparison of the ductility registered by samples variously treated lends some confirmation to the supposition, formerly expressed, that, in all cases, the resilience does not increase in the same proportion as the increase of mean resistance, as a consequence of sustained stress, and this, if a fact, may possibly be considered as corroborating the idea just suggested.*

*Since the above was written, the *Journal of the Franklin Institute* has, in the issue for March, 1874, given an account of experiments made by Com'd'r Beardslee, U. S. N., during which metal strained beyond the elastic limit by tension, exhibited a gain of resistance at a position of earliest set, *i. e.*, an elevation of the elastic limit, from 23,075, to 26,100 pounds per square inch, 13.1 per cent., in seventeen hours. The material was bloom iron turned approximately to one-half square inch section.

A very important fact noted by the experimenter is that an apparent positive action was observed in the metal under strain by which the scale beam was actually thrown up by a force measuring 125 pounds. If this observation is not erroneous, or, if the action was not due to some accidental circumstance, we may have here a measure of the *intensifying effect* above described.

Commander Beardslee has communicated to the writer the experimental confirmation of the fact, deducible from the explanation here given, that this release of internal strain occurs to a nearly equal extent if the strained piece is simply laid aside for a similar interval after it has been given a set.

NOTE.—In further confirmation of the increase of resistance to strain, caused by permitting a metal to rest after the first application, I offer the following, taken at random from my test book: One link Pembroke iron made into form for service, 13-16, pulled first time to 185,000 lbs., when it broke the proving chain; the next day it was pulled again until broken, standing the extraordinary strain of 262,200 lbs., other links from same bar having broken very uniformly at about 240,000 lbs.

From uniform bars of 1¼ inch chain iron (Pembroke), a number were left unbroken, after a day's testing, having broken shackles, end links, etc., at from 90 to

The discovery of this elevation of the elastic limit in all metals examined is also probably confirmatory of this idea.

If the explanation, just offered, of the apparent strengthening action of prolonged stress is correct, the conclusions of Vicat are not overthrown, although evidently not fully justified by his own experiments, and although the intervening forty years of engineering practice have not produced evidence which may be considered as confirmatory of them.

The same molecular movement, or flow, which rearranges the internal forces and relieves internal strain, may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

Should this prove to be the fact, it would seem allowable to conclude that the forces of polarity and cohesion are not identical. The cause of the apparent increase of strength of iron, with increase of temperature, is seen to be explained by this relief of internal strain, which occurs most readily at high temperatures.

The experiments of the writer have not indicated the possibility of continued flow, and, consequently of ultimate rupture, except under stress, increasing in intensity up to the full maximum resistance of the material.* They do not, therefore, confirm Vicat's deductions, and the inference would seem, on the contrary, to be—that structures of metal do not become weakened with age, except as injury occurs by corrosion, or by overloading. The experiments of Roebling† and his opinion, as expressed in his report on the Niagara Suspension Bridge, are apparently correct.

Kirkaldy, also, concludes that the additional time occupied in testing certain specimens of which he determined the elongation "had no injurious effect in lessening the amount of breaking strain."‡ An

100,000 lbs. Of the links which were broken the first day, none went over 100,000 lbs. The next day the unbroken ones were submitted to pulls until broken, and now went under 100,000, and then ran up to 102, 106, 108, and in one link, on the sixth pull, to 114,200 lbs. L. A. Beardslee.

* Compare Kirkaldy—*Experiments on Wrought Iron and Steel*—pp. 62–69; also see the plates given by Styffe, exhibiting curves for tension.

† *Journal Franklin Institute*, 1860; Vol. XL, p. 360.

‡ *Experiments on Wrought Iron and Steel*, pp. 62, 83.

examination of his tables shows those bars which were longest under strain to have had highest average resistance.

22. Wertheim supposed that greater resistance was offered to rapidly, than to slowly, produced rupture; Kirkaldy concludes that the contrary is the case. Redtenbacher* and Weisbach† assume the law of resistance to be the same beyond the limit of elasticity as within it, and deduce formulas for resistance to shock which are widely inaccurate.

The experiments of the writer prove that, as had already been indicated by Kirkaldy (whose results, however, had been looked on by many of the profession with some suspicion), a lower resistance is offered as the stress is more rapidly applied. This conspires with *vis viva* to produce rupture.

This is seen at *w*, No. 101, Plate III, where a sudden increase of velocity produced a depression of the line, at the angle 110°, and it is exhibited in a much more marked degree in No. 118.

In the latter example, the strain was gradually applied until the point *a* was reached, when, with a suddenly applied force, a motion estimated at about one-tenth of a foot per second, was obtained and, immediately at *b*, the resistance fell off very considerably, the pencil dropping to *c*. Again resuming the slowest movement, about one hundredth of a foot or less per second, resistance rose again to *d*. A repetition of the rapid movement between *d* and b^1, was followed by a loss of resistance again from b^1 to c^1, and, as is seen by the diagram, this occurred whenever the experiment was repeated. At *k*, distortion by a very slow movement was resumed, and continued until the specimen broke. Here we have, probably, the first direct determination of this question, in which the effect of *vis viva* does not appear.

We may, therefore, conclude that the rapidity of action, in cases of shock, and where materials sustain live loads, is a very important element in the determination of their resisting power not only for the reason given already in paragraph 3 of this section, but because *the more rapidly the metal is ruptured, the less is its resistance to rupture.* This loss of resistance is about 15 per cent.‡ in No. 118.

The cause of this action we may presume to bear a close relation to that operating to produce the opposite phenomenon of the elevation

* *Der Maschinenbau*, Vol. I. † *Mechanics of Engineering, etc*

‡ Compare Kirkaldy, p. 83. where experiments, which are possibly affected by the action of *vis viva* indicate a very similar effect.

of the elastic limit by prolonged stress, and it may probably be simply another illustration of the effect of internal strain.

With a very slow distortion, the "flow" already described occurs, and but a small amount of internal strain may be produced, since, by the action noticed when left at rest, this strain relieves itself as rapidly as produced. A more rapid distortion produces internal strain more rapidly than relief can take place, and the more quickly it occurs, the less thoroughly can it be relieved, and the more is the total resistance of the piece reduced. Evidence confirmatory of this explanation is found in the fact that bodies most homogeneous as to strain exhibited the least of these effects.

It does not seem impossible that, at extremely high velocities, the most ductile substances may exhibit similar behavior, when fractured by shock, or by a suddenly applied force, to substances which are really comparatively brittle.

In the production of this effect, which has been frequently observed in the fracture of iron, although the cause has not been recognized, the inertia of the mass attacked and the actual depreciation of resisting power just observed, conspire to produce results which would seem quite inexplicable, except for the evidently great concentration of energy here referred to, which, in consequence of this conspiring of inertia and reduced resistance, brings the total effort upon a comparatively limited portion of the material, producing the short fracture with its granular surfaces, which is the well known characteristic of sudden rupture.

Any cause acting to produce increased density, as reduction of temperature, evidently must intensify this action of suddenly applied stress.

The liability of machinery and structures to injury by shock is thus greatly increased, and it is quite uncertain what is the proper factor of safety to adopt in cases in which the shocks are rapidly produced. This uncertainty must remain until further experiment shall be made the basis of a correct mathematical expression of the natural laws involved in the problem.

Meantime the precautions to be taken by the engineer are: To prevent the occurrence of shock as far as possible, and to use in parts exposed to shock, light and elastic members, composed of the most ductile materials available, giving them such forms as shall distribute the distortion as uniformly and as widely as possible.

23. The behavior of materials subjected to sudden strain is thus

seen to be so considerably modified by both internal and external conditions, which are themselves variable in character, that it may still prove quite difficult to obtain mathematical expressions for the laws governing them. It is not improbable, however, that an approximation, of sufficient accuracy for all cases which frequently arise in practice, may be obtained by a study and comparison of experimental results obtained, as above, by the method here adopted, and one which seems peculiarly adapted to the work.

A carefully conducted series of experiments giving quantitative results would be of great value. Without such a research no reliable knowledge can be obtained of the law of depreciation, and no useful formulas can be devised for use in calculation. The experiments made by the writer are not yet sufficiently numerous or precise to serve as data from which to deduce equations.

24. The Elasticity of the Metals.—The examination of the "elasticity line" will be found to present some facts of interest.

It will be seen that, in every case, the line produced by the descent of the pencil is not precisely coincident with that formed by its rise. This is not due to the friction of the machine, as that would not cause the decided difference observable in the form of the curve. It may be partly due to the fact that the set produced is partly temporary.*

An attempt was made to determine its law by the following method:

A steam gauge having a recording apparatus, in which the paper was moved horizontally, at a uniform rate, by a well-constructed clock, was kindly furnished by the Messrs. Edson, of the New York Recording Gauge Co.

This was set up by the side of the machine, upon a stand on which could be clamped the test piece. The latter carried a light, long pencil holder, so arranged as to traverse the paper in a direction at right angles to that of the motion given it by the clock. An angular motion in the specimen of 0·05° would be readily observed. The specimen was given a degree of torsion of from 10° to 360°, in different cases, and was then rapidly transferred to the stand, where the restoration of form would record itself upon the moving paper, forming a curve of which the ordinates would represent the restoration of form, and the abscissas would be proportional to the time.

* Morin, *Resistance des Materiaux*, p. 10.

In all cases observed, the restoration of form, by loss of temporary set, was so rapid as to have become completed before the specimen could be placed in the recording apparatus, and the record made a straight line invariably.

The conclusion which has finally been deduced from a study of the diagrams obtained is, that the peculiar feature here alluded to is a consequence of an internal molecular friction, the existence of which has already been long suspected by the writer, and probably by many other experimenters.

An illustration of a similar action probably occurs in the behavior of iron under magnetic action. Magnetization produced in bars of various qualities of iron and steel during important researches of Dr. Joule* and Prof. Tyndall,† proved this behavior to be common to all, when the change of form was produced, within a very minute range even, by magnetic force. Dr. Mayer has more recently‡ examined this peculiar form of molecular action with great skill and thoroughness. Its existence is undoubtedly well proven, and the lines, above referred to, on the strain-diagrams seem to exhibit its effect very clearly. Possibly the rise from *f* to *g*, No. 118, Plate III, is due to such friction.

25. The evident proof found, in the parallelism of all elasticity lines in each diagram, of the fact, first noted by some of the earliest experimenters in this field, that elasticity remains quite unimpaired up to the point at which rupture commences, has been already adverted to.

Coulomb describes a series of curious and instructive experiments which may assist in determining the molecular action occurring in these instances where great distortion and great permanent displacement of particles takes place without loss of elasticity.§

He found this to occur, not only with metal wires, but with threads of fine clay, 1–12 of an inch in diameter and 11 feet long, which could be twisted 5½ turns repeatedly without set and without apparent loss of elasticity. Turning the thread through a wider range of torsion, it always returned but 5½ revolutions, and in each new position of set exhibited the same elasticity as before.

* *Philosophical Magazine*, 1874. † *Researches on Diamagnetism*, etc., 1870.

‡ "*Effects of Magnetism in changing dimensions of iron and steel bars*," by A. M. Mayer, Ph. D.; Stevens' Institute of Technology, 1872. *American Journal of Science and Arts*, 1873.

§ *Lecture Notes on Physics*, Mayer; *Journal Franklin Institute*, 1868.

The explanation of this action, as illustrated by the strain diagrams of Plates II and III, and by Coulomb's experiments, is probably also to be found in the phenomenon of flow of solids. The restoration of cohesion, in bodies actually separated, exhibits the extent to which this action may proceed. Two freshly cut surfaces of lead when brought together with a moderate pressure cohere firmly; and plates of glass, laid one upon another, sometimes "seize" each other so firmly that they are cut and worked as one piece.* The welding of iron is another and a very familiar illustration of the same action. Cohesion may therefore be actually destroyed and renewed, and molecules may move among each other, changing completely their relative positions, without loss of either strength or elasticity.

The results of these experiments on metal are important as exhibiting the error of the opinion hitherto entertained by many physicists and engineers, among whom was the writer,† that straining metal might weaken it, even when rupture did not commence, and even where no condition of internal strain was induced. It has been here shown that elasticity remains unimpaired, and resistance continually increases up to the point at which incipient fracture takes place. No well proven exception to this law has been observed.

26. While comparing the inclination of the elasticity lines with the initial line, to determine the pressure and the amount of internal strain, it has been noticed that more or less strain seems almost invariably to exist, but that the amount, as indicated by the difference in inclination of the two lines, is not always as well shown by the greater or less curvature of the initial portion of the diagram. The probable reason would seem to be that this strain is not always uniformly distributed. Were the strain considerable and uniformly distributed, the initial line would be strongly convex toward the base line, and would have the parabolic form. Absence of strain is indicated by a straight line rising regularly to the elastic limit, or, in many cases where the elastic limit is very low, and when the material is inelastic and flows without tendency to recoil, concave toward the base, and parabolic. Irregularly distributed strain would modify the parabolic curve, and the amount of strain would determine the total curvature.

The initial and elasticity lines have, therefore, great interest as re-

* *Miller, Chemical Physics*, p. 67. † *Journal Franklin Institute.*

vealing important and otherwise unrecognizable properties of the material.

It has been remarked that the difference of inclination just referred to, proves the truth of the assertion of Hodgkinson that every load produces a set. It can now be readily seen why this should usually be the fact, and also that, although it is true, it does not necessarily indicate injury of the material.

Since, in its ordinary state, many sets of particles are usually in a condition of maximum strain, the slightest application of external force to the piece will destroy the existing equilibrium among these conflicting forces within the mass, producing a change of form, and either rupturing or producing a flow of those particles which are most strained, and thus causing a new condition of equilibrium, the piece returning only approximately to the original form when relieved. The greater or less the applied force, the greater or less the number of displaced particles, but it is only when the set becomes nearly proportional to the distortion that it assumes the character in which it is looked upon as a serious effect.

With perfectly homogeneous materials, free from internal strain, no such action would be noticed, and the earliest set would occur beyond the elastic limit, which limit is here considered to be attained when the set becomes proportional to the distortion.

27. The very minute range of distortion within the elastic limit is shown by the strain-diagrams very beautifully. This point is usually reached with the first 5° of torsion, and where internal strain has been eliminated it is frequently found within 2°, the corresponding extension being much less than ·0001.

Captain Rodman, who has made the most delicate determination yet published,* detects a set of 0·000,001,4 after an extension of 0·000,27 in a specimen of cast-iron, and the elastic limit, as here defined, is reached after an elongation of about 0·0003, the point not being however, very accurately determinable on account of the insensible change of rate, as already observed, in the strain-diagrams of cast-iron.

The immense magnification on the strain-diagrams, obtained with the torsion machine, of the elongation at the commencement of the curve, enables the behavior of the materials within this minute, yet most important, portion of the entire range to be perfectly represented

* *Experiments on Metals for Cannon, etc.* Rodman, pp. 157-167.

and permits its examination in a most satisfactory manner.

28. The Influence of Variations of Temperature.—The effect upon the mechanical properties of metal of variations of temperature has long been a subject of debate, and one which has not even yet been satisfactorily settled by experiment.

A *priori* it would appear that, in a perfectly homogeneous material, entirely free from internal strain, change of temperature would produce an alteration of strength and of ductility which would both be the reverse, in direction, of the variation of temperature.

The forces acting to produce mechanical changes being, probably, cohesive force, on the one hand, resisting external forces tending to produce distortion or rupture, while the force produced by the energy of heat-motion conspires with external force to produce that distortion, and the molecules being, at every instant in equilibrium between the force of cohesion on the one side, and the sum of the other two forces mentioned, on the other, variations of form must ensue with every change in the relative magnitudes of these forces. A change of temperature produced by an increment of heat energy, it would appear, must produce a reduction of cohesion by separation of particles, and the opposite change must cause an increase of cohesion by their approximation. Increase of temperature, by reducing the range of action of cohesion by separating particles, and causing them to approach the limit of reach of cohesive force, would reduce ductility, and the opposite change of temperature would increase extensibility. The effect on resilience, the product of ductility and strength, would evidently be still more marked than the variation of its factors.

The peculiar behavior of zinc, and the often observed brittleness of iron, at low temperatures, have given cause for doubting the truth of the above statement, and until the phenomena accompanying variations in homogeneousness of structure and composition, and the introduction or removal of internal strain, have been very thoroughly investigated, it cannot be anticipated that the subject will become well understood. The character of polarity, that force of which the presence constitutes the distinguishing difference between solids and liquids, remains to be determined, and its determination may be expected to throw important light upon this subject.

Experiments of both physicists and engineers have failed, up to the present time, to give as much, and as precise information as is needed to determine satisfactorily what rules should govern the proportions of structures, whether carrying dead loads or subjected to shocks or

blows, at any given temperature below the usual range, or even at the low temperatures to be met during every winter in the latitude of New York.

In a paper recently published* on "Molecular Changes produced by Variations of Temperature," the writer gave the results of a careful investigation of the experimental work previously done, by both philosophers and engineers, in researches bearing upon this important question.

29. The conclusions, as there reached, were the following:—

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion, and polarity.

2. That the force of repulsion is, apparently, heat, motion, or some closely related phase of energy. That the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter, and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant relation to that of magnetic polarity.

3. That the law which governs the variations in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately and for a limited range.

4. That the magnitudes of the intermolecular spaces, and consequently, the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations in intensity of the forces of polarity and those forces which determine intermolecular distances.

6. That, at the "absolute zero" (— 461·2° Fahr.), cohesion, and consequently the strength of the material has, probably, its maximum value, heat-energy having disappeared.

7. That, at very high temperatures, heat-energy exerts a separating force upon particles, which entirely overcomes the other forces, and matter, assuming the gaseous state, requires the action of extraneous forces to preserve its volume unchanged.

8. That, at intermediate points, matter, in either the solid or the liquid states, exhibits a definite degree of separation of molecules

* *Iron Age*, June, 1873; *Van Nostrand's Magazine*, July, 1873; *Jour. Frank. Inst.* 1873; *London Jour.*, Jan., 1874. Also in pamphlet, p. 29. D. Van Nostrand.

which is determined by the intensity of the repulsion due to heat-motion, a position of equilibrium being assumed, which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce change of volume. The amount of this force is determined, for any given extent of disturbance, by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature.

The sum of the applied force, and the force consequent upon the presence of heat-motion, must exceed cohesive force to produce dilatation, while this cohesive force, added to externally applied force, must exceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liquid states of matter seems due to the action, in the former, of the force of polarity, which gives stability of form, while, in the latter, this force is extremely feeble, disappearing altogether when the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the coexistence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, with solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience, or power of resisting shocks and of carrying "live loads." This change is usually opposite in direction and greater in degree than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that, wherever an exception is observed in the influence upon tenacity, an exception may also be detected in the effect upon resilience. Causes which produce increase of strength seem also to produce a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that, (as to tenacity), the general law holds good with that metal.

14. That iron exhibits marked deviations from the law between or-

dinary temperatures and a point somewhere between 500° and 600° Fahr., the strength increasing between these limits to the extent of about 15 per cent. with good iron. The variation becomes more marked and the results more irregular as the metal is more impure.

15. That above 600° F. and below 70°, the general law holds good for iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from 0·02 to 0·03 per cent. for each degree Fahrenheit, while its resilience decreases in a higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value, or less, at 10° F. when cold-short, and, in the latter case, the set may be less than one-fourth that noted at a temperature of 84° Fahr.

16. That the viscosity, ductility and resilience of metals are determined by identical conditions, and that the fracture of iron at low temperatures, has, accordingly, been found to be characteristic of a brittle material, while at the higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks in the first case, with slight permanent set and a short granular fracture, and in the latter with frequently a considerable set and a form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches a welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperature, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates to a great degree, the effects of low temperature in producing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied, and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

"The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining 'dead' loads at low temperatures, but that they do lose to a very serious extent their power of sustaining shocks or of resisting sharp blows, and that the factors of safety in structures, need not to be increased in the former case, where exposure to severe cold is apprehended,

but that machinery, rails, and other constructions which are to resist shocks, should have larger factors of safety, and should be most carefully protected, if possible, from extreme temperatures."

30. The conclusions above given were deduced from the physical investigations of Boscovich, Coulomb, Henry, Powell, Cagniard de la Tour, Andrews, Faraday, Wartmann ,Robinson, Gaudin, Thompson, Rankine and others, and from the more purely technical researches of Professors Johnson and Norton, Fairbairn, Kirkaldy, Brockbank, Joule, Spence, Styffe and Sandberg.

An apparent discrepancy of results from which some experiments seemed to indicate weakness, and others strength of metals as a consequence of reduced temperature, was explained by the fact that those which seemed to prove the first conclusion, were cases in which the metal was tested by blows, and those proving the reverse were tests made by steady strain. The deduction (11), made above, that the result of change of temperature, by producing changes of ductility, which were the reverse of those produced in tenacity, and that the same bar might thus exhibit a higher resistance to static stress while less capable of resisting shock, explained the seeming contradiction.

31. It was evident that, to determine satisfactorily the real effect of changes of temperature, it was necessary to obtain a series of experimental determinations of the simultaneous action of such variations upon both strength and resilience. Such experiments could readily be made by the method here pursued, and a considerable number of observations are represented by strain-diagrams on plate III.

In these experiments, the machine and the test pieces were placed in the open air, where, changing in temperature with the atmospheric changes, no error could arise by transfer of heat during the experiments. The machine and specimens submitted to test were always of the same temperature.

The mildness of the past winter has precluded the determination of the behavior of iron at temperatures very far below the freezing point, the lowest reached being 10° Fahr.

This is the more to be regretted since, as will be seen, there exists a possible change of law near the Fahrenheit zero, and it is extremely important to ascertain whether this indication of an anomaly arises from irregularity in the quality of specimens, nominally of the same grade, or whether it is a real variation of the effect of change of temperature.

As no previously made experiments combine, in the manner here presented, the various effects of heat upon the mechanical properties of the metals, the results obtained are given as a beginning, and the conclusions which are deduced from them are given as merely probable, while it is to be hoped that other members of the profession, who may be so situated that they can readily continue the work at points in the north and north-west where a temperature far below zero is reached, will make more complete and instructive researches during succeeding winters.

It is apparently quite impossible to avoid error if the attempt is made to experiment with specimens cooled down by freezing mixtures, and the writer would only feel justified in presenting the results of out-of-door work.

32. Referring to Plate III, the strain-diagrams of the best, and of medium tool steel, of German and double shear, of the several grades of iron and of copper and bronze are given, for temperatures from 70° down to 10° Fahr. A diagram is also given in which the horizontal scale of the plate is taken to represent absolute temperatures on a one-fourth scale, and at ordinates representing respectively 10°, 18°, 25° and 70°, the resistances of the several specimens are laid off, and dotted lines connecting them indicate the rate of variation of strength with temperature.

It will be seen that with the single exception of a scrap gray cast iron, presumably unusually impure (Nos. 25, 26), the effect seems invariably to have been a simultaneous increase of both strength and ductility with decrease of temperature to 18° and usually to 10° from 70° Fahr. In the case of the cast-iron, the increase of tenacity and reduction of ductility at the lower temperature are equally well exhibited, and the result is a slight decrease of resilience.

It will be noticed that the general trend of the lines in the diagram prepared for comparison of results, is very evidently towards a point on the scale (250°), corresponding to a temperature of 1000° above the absolute zero, at which point were the diminutions proportioned to temperature, the metals would lose all cohesion. Since, however, the law as determined approximately by the Committee of the Franklin Institute, is expressed by a parabolic equation, the fact that their melting points are nearer 3000° or perhaps 4000° Fahr. above the absolute zero, does not conflict with the results of experiment.

33. Comparing the several specimens of "good cast-steel," it is found that the four (Nos. 46, 47, 49, 50), whose strain-diagrams are

given, evidently differ nearly as much in their individual properties as in their alteration by temperature. The two pieces tested at 70° Fahr. give a mean of strength, ductility and resilience, which is less than either of the other specimens. The strongest piece was broken at 18° while that tested at 10° is very nearly its equal in that respect, and is more than 10 per cent. better in extensibility and nearly ten per cent. superior in resilience. The difference between the specimens tried at 10° and 70° (average of the two) is about 15 per cent. in ductility and resilience, and rather more than 5 per cent in tenacity. The piece tested at 10° has a limit of elasticity exceeding that of the specimens tested at 70° in about the same proportion.

The double shear steels are irregular, as would be expected from their method of production, but the greatest ductility is shown by the specimen tested at 25° F., and the greatest tenacity by that broken at 25° also. The weakest is that tested at 70°, its loss of strength, ductility and resilience being very striking. The position of the elastic limit varied with that of the ultimate strength. "German" (English) steel exhibits greatest strength at 18° (No. 60), greatest ductility at 70° (No. 58) and greatest resilience at 25° (No. 25).

"Medium crucible" steel seems strongest at 18° Fahr., most ductile and equally resilient at 25°, and weakest, least ductile and least resilient at 70°. Nos. 78, 54, 70 are their strain-diagrams.

Swedish irons (No. 99 and 100) were tried at 25° and 70°, and the result is again that the greatest resistance and greatest extensibility occur at the lowest temperature, the difference here amounting to something less than 10 per cent. at the elastic limit and about one-half as much at the maximum.

A piece of common iron was selected by the blacksmith from his stock as "the worst specimen of cold short iron in the shop." The two specimens, Nos. 130 and 132, were taken from the bar and tested at 10° and 70° Fahr. respectively, with a result which is unexpectedly similar to those already given in the variation of ultimate strength, ductility and resilience. The increase of strength at the lower temperature is apparently nearly 15 per cent. the increase of ductility about the same, and the increase of resilience 30 per cent. At the elastic limit this is reversed, however, the specimen tested at 70° showing the highest elastic resistance. That broken at 10° exhibits a very considerable amount of internal strain, to the presence of which may be attributed the exceptional behavior of these pieces.

A similar difference but opposite in direction and in less amount is noticeable in the Swedish irons, Nos. 99 and 100.

Copper, Nos. 133 and 134, and bronze, Nos. 137, 138, both show a considerably greater strength at 10° than at 70° and a slightly improved ductility. The increase of tenacity and resilience amounts to 20 per cent. and 30 per cent. respectively, the ratio being slightly greater at the limit of elasticity.

Cast-iron exhibits the most striking increase of tenacity, the ratio of increase being above 30 per cent. and in ductility having a mean value of 50 per cent. One specimen, No. 25 *C*, has a serious defect of internal strain, but eliminating that by cutting off the sharply curved lower portion of the line, it would coincide very exactly with the companion specimen, No. 25 *D*, broken at the same temperature, 25°.

34. It would seem, after a study of these experiments and after a comparison with those described by other experimenters, that, although a considerable irregularity, due to differences in material nominally of identical character, tends to obscure them, that we may feel some confidence in drawing the following conclusions in modification and extension of those already given in article 29:

20. That, with pure, well-worked metals, the principle enunciated in article 29 is fully illustrated, and a decrease of temperature is accompanied by increase of strength, ductility and resilience.

21. That materials which are impure and irregular in character may exhibit exceptions to, and even reversals of, that principle in changes of ductility and, while increasing in power of resisting simple stress, may lose their power of resisting shock, by a diminution of temperature.

We may hence feel confidence that, with really good iron or steel, we are not exposed to seriously increased danger of failure of structures at such low temperatures as frequently occur in this latitude.

There is no reason to believe that the familiar effect of phosphorus in "cold-shortening" iron and steel, when cold, has its maximum effect at ordinary temperatures. The experiments of Sandberg would seem to prove this effect to be intensified continually with decrease of temperature.

35. Since the above research was concluded, the writer has become indebted to the thoughtful kindness of Mr. Chas. Francis Adams, Jr., for reports, one of which is that of the Mass. R. R. Commissioners for 1874 containing (page 144, *et seq.*), the result of an investigation of the cause of rail breakage on a considerable number of

railroads in the United States and Canada. The conclusions given are that "cold does not make iron or steel brittle, or unreliable, for mechanical purposes," and that "it was not the rule that the most breakages occur on the coldest days." The introduction of steel, in place of iron rails has caused an almost complete cessation of the breakage of rails (p. 150).

The deduction which would seem proper in comparing these latter statements with the work of Sandberg would seem to be, simply, that the latter experimented with cold-short rails. The same conclusion is given in Sandberg's own statement of the difference between Welsh and French metal.*

36. We still require, to give us reliable information regarding exceptional cases, a series of experiments to determine the action of excessively low temperature, and whether the apparent change of law near the Fahrenheit zero is a natural or a artificial phenomenon. We need to learn precisely the effects of sulphur, phosphorus, and silicon at extremely low temperatures. We need, also, and especially, to learn by experiment whether extremely low temperatures occuring during our winters, produce a serious effect upon iron and steel by the introduction of internal strain as the material decreases in volume and increases in density.

The uncertainty still existing as to the extent to which increased density at low temperatures and reduction of tenacity under sudden strains at all temperatures—phenomena which have been revealed but not measured during the investigations here described—will be recognized by every member of our profession as one which it is exceedingly important to remove. It is hoped that it may not long remain, for it is evident that, although perhaps improbable, it is not impossible that, notwithstanding the increase of both tenacity and ductility by reduction of temperature, these causes may still conspire to produce increased tendency to yield before shock at some unknown low temperature.

37. The peculiarities of fracture, which have been alluded to, are exhibited in the accompanying Plate.

Figures 15 and 16 exhibit the behaviour of a bar of iron made at Catasauqua, Pennsylvania, as broken by Mr. Oliver Williams, at 70°, and again at 20° Fahr. It is selected from among the specimens in the cabinet of the Stevens Institute of Technology. The fracture at 70° (Figure 15) has the fibrous fracture and all the characteristics of

*P. 157, conclusion 3; p. 158, line 4; p. 32, Nos. 21, 24.

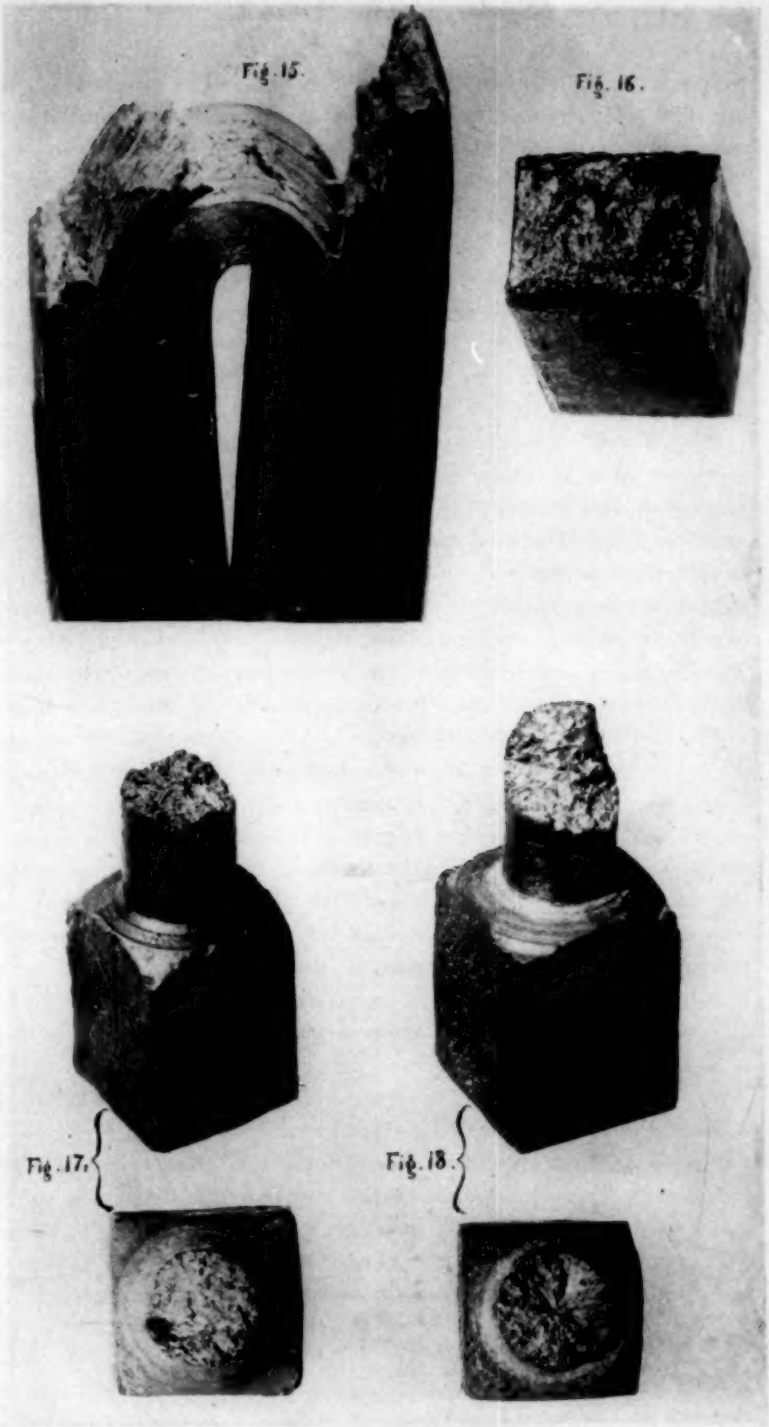
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.

what is generally considered a tough and ductile iron. That at 20° (Figure 16) resembles the break produced by a quick blow in good iron, or by any treatment at ordinary temperatures of a cold short iron. Were the conditions stated not known, it would be supposed that irons like Nos. 1 and 16, Figures 5 and 6, were combined in a single bar.

Figures 18 and 17 illustrate strikingly the difference between the specimens of copper, Nos. 87 and 133, which have been already described and of which the strain-diagram of the one is shown in Plate II, and of the other in Plate III. No. 87 was cast in green sand, and broken at 70° F., while the other was made from the same ingot, but cast in dry sand and broken at 10° Fahr.

The first is unsound in structure in consequence of the dampness of the mould and exhibits a peculiar radiated texture which is probably due to the same cause. The second is distinguished by its compact homogeneous structure probably due to the freedom of the mould from vapor and gases. It presents a beautiful crystalline fracture which is probably due partially, if not principally, to the low temperature at which it was broken.

These fractures are extremely interesting from the strongly typical features which they exhibit as characteristic of the peculiar conditions under which they were produced.

Resume.

37. *En resume*, a review of this investigation of the nature of, and the influences affecting, the distortion and rupture of metals, it would seem allowable to accept, as extremely probable, the following

General Conclusions:

1. That accurate strain-diagrams, in which the behavior of the material, as distortion progresses, and especially about the elastic limit, afford a means of acquiring valuable information respecting the strength, elasticity, homogeneousness, ductility, and resilience of materials, and of tracing the modifications induced by variations of treatment and of composition

2. That internal strain plays a most important part in determining the behavior of materials strained by either static or dynamic stress.

3. That the time, during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking force and the action of

inertia of the piece attacked, but, also, as modifying seriously the conditions of production and relief of internal strain by even simple stresses.

4. That with good materials, cold does not produce injury, but actually improves their power of resisting stress and increases their resilience.

6. That the influence of impurities, of various methods of manufacture, of changes of density with temperature, and of the causes which produce a concentration of the action of rapidly produced distortion and of quick blows, are subjects which still require careful investigation.

7. That experiment confirms the theory as to the behavior of materials, homogeneous in composition, structure, and strain, as expressed *a priori* in 27, and hence a probable deduction that the force of molecular repulsion is heat motion.

SECOND CHEMICAL AND SANITARY REPORT UPON THE WATER SUPPLY OF THE CITIES OF NEWARK AND JERSEY CITY.

By Professor Henry Wurtz.

(Corrected and prepared for this Journal by the Author.)

[Continued from Vol. LXVII, page 436.]

5. *The Rockaway River.*—This stream runs through three towns of some size, Dover, Rockaway and Boonton. A smaller place also, Denville, imparts its drainage. Beginning with Boonton, I do not know whether the canal receives, on the level below the Boonton plane, any of the drainage of lower Boonton, but if so, this can easily be directed into the lower Rockaway. The main difficulty appears to be above Boonton, at Powerville, where the canal crosses and coalesces with the stream, the latter being brought up to the level of the former by the dam at that place. Thus the canal is made to partake of such contaminations as are brought down from the towns and population of the valley above. Whether by extinguishing the Powerville water-rights, and removing the dam, the two could be separated at this point, and the river conducted under the canal, is a question for the engineers to decide. The stream between Powerville and Dover, when observed during July, was seen to be opalescent and particularly offensive to the smell and taste, but during September it was perfectly limpid, inodorous and tasteless.

TABLE I.

Experiments on the Power of, and Quantity of Water discharged by the Westerly Seventy-Two Inch Swain Turbine Water Wheel, in Boott Cotton Mill, No. 5, at

No. of the experim't	Date, 1874.	Temperature		Height of the Regulating gate.	TIME.						Duration of the experim't.	Total number of revolutions of the wheel during the experiment.	Weight in the Scale.	Useful effect, or the friction of the brake.	Total fall acting upon the wheel.	Depth of water on the weir.	Quantity of water passing the weir.	Weight of a Cubic Foot of water.	Total power of the water.	Ratio of the useful effect to the Power expended.	Ratio of the velocity of the exterior circumference of the wheel to the velocity due the fall acting on the wheel.	Quantity of water which passed the wheel, reduced to a uniform fall of 17 feet.	
		Of air in wheel room.	Of water in wheel pit.		Beginning of the experiment.			Ending of the Experiment.															
		Deg. Fahr.	Deg. Fahr.	Inches.	Hours.	Min.	Sec.	Hours.	Min.	Sec.	Seconds.		Pounds Avoir.	Pounds raised one foot per Second.	Feet.	Feet.	Cubic feet per Second.	Pounds.	Pounds raised one foot per Second.			Cubic feet per Second.	
1	Aug. 1, A. M.			3·25	9	17	6·5	9	23	47·5	401·0	450	434·56	36673·8	13·963	1·1940	70·865	62·245	61590·6	0·5954	0·7064	78·193	
2	" "			"	9	37	2·0	9	46	57·0	595·0	650	459·56	37755·2	13·967	1·1993	71·337	"	62018·9	0·6088	0·6876	78·703	
3	" "	75	73·5	"	9	55	55·5	10	7	54·0	718·5	750	484·56	38038·2	13·912	1·2025	71·623	"	62022·1	0·6133	0·6583	79·174	
4	" "			"	10	11	48·5	10	21	28·5	580·0	550	534·56	38121·4	13·928	1·2089	72·196	"	62589·8	0·6091	0·5977	79·761	
5	" "			"	10	27	27·0	10	34	29·0	422·0	350	584·56	36460·5	13·930	1·2122	72·491	"	62855·3	0·5801	0·5227	80·082	
6	" "			"	10	40	9·0	10	46	57·0	408·0	500	385·56	35533·6	13·934	1·1791	69·543	"	60315·8	0·5891	0·7722	76·813	
7	" "			6·50	11	10	0·5	11	17	33·5	453·0	600	646·00	64346·3	13·365	1·5823	108·108	"	89935·6	0·7155	0·8522	121·926	
8	" "			"	11	20	8·5	11	29	7·0	538·5	650	768·87	69794·0	13·276	1·6157	111·549	"	92180·2	0·7571	0·7792	126·228	
9	" "			"	11	31	15·0	11	39	8·5	473·5	550	824·47	72020·4	13·306	1·6296	112·992	"	93583·3	0·7696	0·7490	127·717	
10	" "			"	11	41	19·0	11	50	7·0	528·0	600	849·47	72594·4	13·273	1·6340	113·450	"	93729·5	0·7745	0·7337	128·393	
11	Aug. 1, P. M.			"	1	59	27·5	2	8	23·5	536·0	600	874·47	73615·5	13·287	1·6437	114·461	62·249	94671·2	0·7776	0·7224	129·470	
12	" "			"	2	9	55·0	2	19	4·5	549·5	600	899·47	73859·8	13·286	1·6485	114·963	"	95079·3	0·7768	0·7046	130·043	
13	" "			"	2	25	17·5	2	34	38·5	561·0	600	924·47	74356·5	13·283	1·6535	115·486	"	95490·4	0·7787	0·6903	130·649	
14	" "			"	2	36	13·0	2	47	19·5	666·5	700	949·47	74992·3	13·316	1·6596	116·126	"	96257·8	0·7791	0·6770	131·210	
15	" "			"	2	58	57·5	3	6	43·5	466·0	400	1074·47	69359·5	13·249	1·6641	116·599	"	96163·3	0·7213	0·5547	132·077	
16	" "			13·00	3	23	16·0	3	27	45·0	269·0	500			13·291	1·6616	116·336	"	96250·8		1·1993	131·572	Bra
17	" "			"	3	33	41·5	3	44	8·5	627·0	800	1074·47	103099·0	12·685	2·0618	160·803	"	126974·8	0·8120	0·8427	186·140	
18	" "			"	3	50	26·0	3	58	54·0	508·0	600	1213·22	107761·8	12·712	2·0862	163·666	"	129510·5	0·8321	0·7792	189·268	
19	" "		73	"	4	1	7·0	4	10	52·0	585·0	650	1290·22	107810·0	12·666	2·0983	165·092	"	130166·2	0·8282	0·7344	191·263	
20	" "			"	4	18	8·5	4	24	32·0	683·5	750	1315·22	108532·3	12·703	2·1037	165·730	"	131050·7	0·8282	0·7242	191·722	
21	" "			"	4	29	19·0	4	36	30·5	431·5	450	1365·22	107071·1	12·716	2·1074	166·167	"	131531·0	0·8140	0·6879	192·130	
22	" "			"	4	40	9·5	4	49	7·0	587·5	450	1514·47	95352·6	12·579	2·1015	165·470	"	129567·9	0·7359	0·5553	192·862	
23	Aug. 4, P. M.			2·00	5	12	9·5	5	23	4·5	655·0	950	90·00	9816·6	14·312	0·9143	47·485	62·272	42320·5	0·2320	0·9018	51·753	
24	" "			"	5	25	26·5	5	31	58·0	391·5	550	115·00	12149·7	14·309	0·9207	47·985	"	42756·7	0·2842	0·8736	52·302	
25	" "			"	5	32	34·0	5	41	18·5	524·5	700	148·69	14923·6	14·324	0·9297	48·690	"	43430·6	0·3436	0·8295	53·043	
26	" "			"	5	44	32·0	5	51	5·0	393·0	500	173·69	16618·4	14·279	0·9363	49·209	"	43756·0	0·3798	0·7920	53·694	
27	" "			"	5	51	46·0	5	57	54·5	368·5	450	198·69	18246·9	14·288	0·9403	49·525	"	44064·5	0·4141	0·7599	54·021	
28	" "			"	5	58	37·5	6	5	4·5	387·0	450	223·69	19560·8	14·342	0·9474	50·087	"	44732·9	0·4373	0·7222	54·531	
29	" "			"	6	8	23·5	6	20	47·5	744·0	750	284·56	21572·5	14·283	0·9611	51·177	"	45518·7	0·4789	0·6274	55·833	
30	Aug. 5, A. M.			"	7	38	42·5	7	47	19·0	516·5	500	294 56	21444·3	14·228	0·9616	51·217	62·268	45375·9	0·4726	0·6037	55·985	
31	" "			"	7	48	19·5	7	57	30·5	551·0	450	344·56	21162·3	14·190	0·9673	51·673	"	45657·7	0·4635	0·5100	56·559	
32	" "		70·5	3·00	8	8	22·5	8	16	33·5	491·0	400	528·72	32392·3	13·979	1·1701	68·748	"	59841·2	0·5413	0·5125	75·813	
33	" "			"	8	18	17·5	8	26	42·5	505·0	500	464·69	34600·3	13·973	1·1653	68·325	"	59447·8	0·5820	0·6230	75·368	
34	" "			"	8	29	7·0	8	37	2·0	475·0	500	439·69	34806·5	13·977	1·1617	68·009	"	59189·5	0·5881	0·6623	75·004	
35	" "			"	8	39	20·0	8	45	24·5	364·5	400	414·69	34223·5	13·972	1·1569	67·588	"	58802·0	0·5820	0·6906	74·553	
36	" "			"	8	46	8·5	8	54	8·0	479·5	550	389·69	33614·9	13·960	1·1502	67·002	"	58241·8	0·5772	0·7221	73·938	
37	" "			"	8	56	56·0	9	3	53·0	417·0	500	364·69	32884·8	13·988	1·1445	66·504	"	57925·4	0·5677	0·7541	73·315	
38	" "			"	9	5	54·0	9	12	36·0	402·0	500	339 69	31773·5	14·026	1·1377	65·912	"	57565·9	0·5519	0·7812	72·564	
39	" "			"	9	14	28·0	9	23	40·0	552·0	750	281·00	28712·2	14·011	1·1196	64·346	"	56137·5	0·5115	0·8538	70·878	
40	" "			"	9	25	59·5	9	30	37·5	278·0	400	231·00	24995·7	14·049	1·1051	63·100	"	55199·8	0·4528	0·9030	69·411	
41	" "		70·5	4·00	9	42	35·0	9	48	34·0	359·0	550	231·00	26614·5	13·899	1·2152	72·761	"	62971·6	0·4226	0·9666	80·469	
42	" "			"	9	51	23·5	9	55	57·5	274·0	400	298·81	32805·2	13·853	1·2430	75·272	"	64929·2	0·5052	0·9226	83·384	
43	" "			"	9	57	9·5	10	2	33·5	324·0	450	367·00	38332·9	13·812	1·2646	77·242	"	66431·8	0·5770	0·8791	85·694	
44	" "			"	10	3	51·5	10	10	20·5	389·0	500	443·81	42899·8	13·782	1·2918	79·748	"	68437·6	0·6268	0·8144	88·570	
45	" "			"	10	11	43·0	10	19	18·5	455·5	550	496·94	45124·9	13·764	1·3106	81·495	"	69845·7	0·6461	0·7656	90·570	
46	" "			"	10	20	1·0	10	27	51·0	470·0	550	521·94	45932·8	13·741	1·3168	82·074	"	70224·3	0·6541	0·7426	91·289	
47	" "			"	10	29	18·5	10	36	41·0	442·5	500	546·94	46476·6	13·703	1·3213	82·495	"	70389·4	0·6603	0·7180	91·885	
48	" "			"	10	37	27·0	10	43	31·5	364·5	400	571·94	47201·0	13·703	1·3272	83·048	"	70861·4	0·6661	0·6973	92·501	
49	" "			"	10	45	9·5	10	52	31·0	441·5	450	621·94	47672 5	13·699	1·3362	83·894	"	71562·5	0·6662	0·6478	93·457	
50	" "			5·00	11	15	43·0	11	24	10·5	507·5	550	713·31	58135·7	13·440	1·4706	96·865	"	81064·5	0·7172	0·6954	108·941	
51	" "			"	11	24	59·0	11	30	42·0	343·0	350	771·19	59179·7	13·482	1·4794	97·736	"	82048·8	0·7213	0·6587	109·749	
52	" "			"	11	33	21·5	11	40	27·5	426·0	400	828·34	58492·0	13·444	1·4882	98·609	"	82548·7	0·7086	0·6024	110·886	
53	" "			"	11	41	27·5	11	42	29·5	62·0	50	887·03	53796·5	13·436	1·4803	97·825	"	81843·5	0·6573	0·5175	110·037	
54	Aug. 5, P. M.			"	2	44	11·5	2	50	50·0	398·5	350	862·03	56937·7	13·483	1·4846	98·251	"	82487·9	0·6906	0·5626	110·324	
55	" "			"	3	2	7·0	3	9	29·5	442·5	500	680·62	57836·1	13·479	1·4613	95·948	"	80529·8	0·7182	0·7239	107·753	
56	" "			"	3	10	13·0	3	18	48·5	515·5	600	655·62	57386·9	13·542	1·4578	95·603	"	80615·6	0·7119	0·7440	107·116	
57	" "			"	3	19	30·5	3	26	30.5	420·0	500	630·62	56458·1	13·546	1·4502	94·856	"	80009·7	0·7056	0·7608	106·264	
58	" "			"	3	27	50·5	3	35	9·0	438·5	550	580·62	54767·5	13·552	1·4370	93·564	"	78954·8	0·6937	0·8014	104·793	
59	" "			"	3	36	25·0	3	43	16·0	411·0	550	505·62	50884·2	13·589	1·4131	91·240	"	77203·4	0·6591	0·8539	102·050	
60	" "			"	3	44	59·0	3	51	49·0	410·0	600	370·12	40733·1	13·660	1·3674	86 850	"	73872·7	0·5514	0·9314	96·887	
61	" "			6·00	4	4	51·0	4	10	21·5	330·5	500	369·56	42045·7	13·539	1·4531	95·141	"	80208·3	0·5242	0·9671	106·610	
62	" "			"	4	11	29·5	4	18	22·5	413·0	600	446·37	48767·9	13·518	1·4843	98·222	"	82677·0	0·5899	0·9294	110·148	
63	" "			"	4	19	34·0	4	26	50·0	436·0	600	539·56	55839 6	13·458	1·5167	101·455	"	85019·7	0·6568	0·8824	114·027	
64	" "			"	4	28	7·0	4	36	2·0	475·0	600	656·94	62405.3	13·381	1·5513	104·947	"	87442·4	0·7137	0·8123	118·290	

| | | |

ch Swain Turbine Water Wheel, in Boott Cotton Mill, No. 5, at Lowell, Mass.

the	Quantity of water passing the weir. Cubic feet per Second.	Weight of a Cubic Foot of water. Pounds.	Total power of the water. Pounds raised one foot per Second.	Ratio of the useful effect to the Power expended.	Ratio of the velocity of the exterior circumference of the wheel to the velocity due the fall acting on the wheel.	Quantity of water which passed the wheel, reduced to a uniform fall of 17 feet. Cubic feet per Second.	REMARKS.
	70·865	62·245	61590·6	0·5954	0·7064	78·193	
	71·337	"	62018·9	0·6088	0·6876	78·703	
	71·623	"	62022·1	0·6133	0·6583	79·174	
	72·196	"	62589·8	0·6091	0·5977	79·761	Speed Gate open one quarter, nearly.
	72·491	"	62855·3	0·5801	0·5227	80·082	
	69·543	"	60315·8	0·5891	0·7722	76·813	
	108·108	"	89935·6	0·7155	0·8522	121·926	
	111·549	"	92180·2	0·7571	0·7792	126·228	
	112·992	"	93583·3	0·7696	0·7490	127·717	
	113·450	"	93729·5	0·7745	0·7337	128·393	
	114·461	62·249	94671·2	0·7776	0·7224	129·470	Speed Gate open one half, nearly.
	114·963	"	95079·3	0·7768	0·7046	130·043	
	115·486	"	95490·4	0·7787	0·6903	130·649	
	116·126	"	96257·8	0·7791	0·6770	131·210	
	116·599	"	96163·3	0·7213	0·5547	132·077	
	116·336	"	96250·8		1·1993	131·572	Brake loose on friction pulley.
	160·803	"	126974·8	0·8120	0·8427	186·140	
	163·666	"	129510·5	0·8321	0·7792	189·268	
	165·092	"	130166·2	0·8282	0·7344	191·263	Speed Gate fully open, nearly.
	165·730	"	131050·7	0·8282	0·7242	191·722	
	166·167	"	131531·0	0·8140	0·6879	192·130	
	165·470	"	129567·9	0·7359	0·5553	192·362	
	47·485	62·272	42320·5	0·2320	0·9018	51·753	
	47·985	"	42756·7	0·2842	0·8736	52·302	
	48·690	"	43430·6	0·3436	0·8295	53·043	
	49·209	"	43756·0	0·3798	0·7920	53·694	
	49·525	"	44064·5	0·4141	0·7599	54·021	
	50·087	"	44732·9	0·4373	0·7222	54·531	
	51·177	"	45518·7	0·4739	0·6274	55·833	
	51·217	62·268	45375·9	0·4726	0·6037	55·985	
	51·673	"	45657·7	0·4635	0·5100	56·559	
	68·748	"	59841·2	0·5413	0·5125	75·813	
	68·325	"	59447·8	0·5820	0·6230	75·363	
	68·009	"	59189·5	0·5881	0·6623	75·004	
	67·588	"	58802·0	0·5820	0·6906	74·553	
	67·002	"	58241·8	0·5772	0·7221	73·938	
	66·504	"	57925·4	0·5677	0·7541	73·315	
	65·912	"	57565·9	0·5519	0·7812	72·564	
	64·346	"	56137·5	0·5115	0·8538	70·878	
	63·100	"	55199·8	0·4528	0·9030	69·411	
	72·761	"	62971·6	0·4226	0·9666	80·469	
	75·272	"	64929·2	0·5052	0·9226	83·384	
	77·242	"	66431·8	0·5770	0·8791	85·694	
	79·748	"	68437·6	0·6268	0·8144	88·570	
	81·495	"	69845·7	0·6461	0·7656	90·570	
	82·074	"	70224·3	0·6541	0·7426	91·289	
	82·495	"	70389·4	0·6603	0·7180	91·885	
	83·048	"	70861·4	0·6661	0·6973	92·501	
	83·894	"	71562·5	0·6662	0·6478	93·457	
	96·865	"	81064·5	0·7172	0·6954	108·941	
	97·736	"	82048·8	0·7213	0·6537	109·749	
	98·609	"	82548·7	0·7086	0·6024	110·886	
	97·825	"	81843·5	0·6573	0·5175	110·037	
	98·251	"	82487·9	0·6903	0·5626	110·324	
	95·948	"	80529·8	0·7182	0·7239	107·753	
	95·603	"	80615·6	0·7119	0·7440	107·116	
	94·856	"	80009·7	0·7056	0·7608	106·264	
	93·564	"	78954·8	0·6937	0·8014	104·793	
	91·240	"	77203·4	0·6591	0·8539	102·050	
	86 850	"	73872·7	0·5514	0·9314	96·887	
	95·141	"	80208·3	0·5242	0·9671	106·610	
	98·222	"	82677·0	0·5899	0·9294	110·148	
	101·455	"	85019·7	0·6568	0·8824	114·027	
	104·947	"	87442·4	0·7137	0·8123	118·290	
	106·411	"	88172·4	0·7373	0·7732	120·274	

95·141	"	80208·3	0·5242	0·9671	106·610	
98·222	"	82677·0	0·5899	0·9294	110·148	
101·455	"	85019·7	0·6568	0·8824	114·027	
104·947	"	87442·4	0·7137	0·8123	118·290	
106·411	"	88172·4	0·7373	0·7732	120·274	
107·821	"	89662·9	0·7494	0·7429	121·648	
108·221	"	89725·7	0·7547	0·7263	122·283	
108·795	"	90195·3	0·7578	0·7110	122·936	
110·092	"	91044·1	0·7608	0·6689	124·556	
111·239	"	92061·4	0·7543	0·6298	125·806	
110·846	"	91736·3	0·7290	0·5761	125·361	
103·590	62·272	86375·4	0·5431	0·9814	116·722	
108·785	"	90321·4	0·6474	0·9142	122·837	
113·752	"	93495·7	0·7303	0·8399	129·096	
116·714	"	95676·5	0·7662	0·7830	132·634	
118·453	"	96939·7	0·7797	0·7450	134·723	
118·897	"	97184·7	0·7855	0·7320	135·310	
119·268	"	97309·2	0·7906	0·7184	135·856	
120·541	"	98663 1	0·7901	0·6896	137·087	
121·563	"	99075·4	0·7870	0·6575	138·544	
121·563	"	99287·4	0·7705	0·6144	138·396	
112·908	"	93337·0	0·5722	0·9794	127·771	
116·683	"	95774·2	0·6504	0·9328	132·513	
120·668	"	98677·3	0·7109	0·8831	137·294	
123·572	"	100443·5	0·7558	0·8396	141·022	
126·131	"	102240·8	0·7848	0·7972	144·142	
127·200	"	103274·2	0·7945	0·7704	145·247	
128·447	"	103734·1	0·8031	0·7380	147·060	
129·196	"	104403·9·	0·8056	0·7264	147·872	
130·253	"	105184·6	0·8061	0·6979	149·133	
130·503	"	104745·2	0·8005	0·6609	149·878	
130·842	"	105367·2	0·7953	0·6431	150·016	
130·503	"	104785·8	0·7770	0·6122	149·849	
102·954	62·260	86136·4	0·2163	1·1458	115·798	
110·525	"	90812·6	0·3998	1·0752	125·444	
117·040	"	95794·1	0·5360	1·0137	133·096	
123·293	"	100635·3	0·6428	0·9536	140·398	
128·208	"	103665·0	0·7257	0·8880	146·685	
132·538	"	106935·6	0·7803	0·8290	151·803	
136·274	"	109211·6	0·8157	0·7664	156·608	
137·938	"	110184·4	0·8270	0·7360	158·780	
137·994	"	109489·9	0·8266	0·7169	159·379	
138·839	"	110956·3	0·8288	0·7098	159·780	
139·051	"	111090·8	0·8214	0·6891	160·049	
138·795	"	110428·1	0·8162	0·6676	160·085	
139·163	"	110937·3	0·8075	0·6492	160·352	
139·051	"	110311·6	0·7635	0·5773	160·613	
128·566	"	103370·3	0·6208	0·9692	147·509	
138·661	"	110589·4	0·7707	0·8517	159·737	
144·842	"	114887·4	0·8235	0·7638	167·314	
143·263	"	113652·8	0·8308	0·7622	165·478	Repetition of experiment 110.
143·984	"	113678·0	0·8319	0·7315	166·710	
144·774	"	114292·8	0·8363	0·7082	167·631	
144·559	"	113718·3	0·8154	0·6604	167·681	
145·158	"	114813·0	0·7966	0·6244	167·917	
138·795	"	111153·9	0·7035	0·9275	159·561	
150·459	"	118359·1	0·8289	0·7598	174·524	
151·501	"	119226·3	0·8326	0·7227	175·698	
151·547	"	118828·4	0·8168	0·6798	176·072	
151·696	"	119436·4	0·7937	0·6372	175·882	
152·488	"	119604·6	0·7796	0·6049	177·138	
143·443	"	114036·9	0·6902	0·9499	165·510	
156·703	"	122158·8	0·8385	0·7490	182·592	
157·376	"	122223·1	0·8288	0·7126	183·722	
158·132	"	123302·2	0·8138	0·6775	184·235	
158·166	"	123457·4	0·7972	0·6398	184·180	
158·457	"	123211 0	0·7747	0·5996	184·873	
120·392	62·272	98203·9	0·2061	1·1738	137·152	
137·871	"	110581·6	0·4991	1·0683	158·395	
149·133	"	117041·9	0·6904	0·9683	173·206	
158·877	"	123471·8	0·8027	0·8660	185·429	
161·225	"	124814·5	0·8294	0·8083	188·532	
162·538	"	125223·8	0·8357	0·7701	190·528	
163·572	"	126387·3	0·8340	0·7588	191·462	
163·607	"	125986·6	0·8323	0·7412	191·828	
164·243	"	126496·7	0·8297	0·7273	192 558	
164·243	"	126670·6	0·8201	0·7057	192·426	
164·785	"	127037·5	0·8224	0·7098	193·100	
164·384	"	126646·6	0·8067	0·6813	192 693	
164·526	"	126899·0	0·7992	0·6635	192·749	
164·585	"	126893·2	0·7821	0·6264	192·857	
165·033	"	127423·8	0·7458	0·5700	193·242	
162·855	"	125741·9	0·6274	0·4376	190·692	
117·841	"	96666·1		1·1928	133·869	Brake loose on friction pulley.
151·788	"	118907·9	0·	0·	176·450	} Wheel prevented from revolving by the brake; the
151·696	"	118609·3	0·	0·	176·512	} weight in the scale bal'nced the pressure on the buckets.

The result of the analysis of the Passaic Falls should teach us, however, not to trust too much to such external appearances. Inquiry in Dover elicited the fact that the citizens who occupy the thickly-settled river bottom are greatly dissatisfied with their *wells*, attributing much sickness to bad water. A few words on this head will not be out of place. It may be asserted that the wells, in a river valley filled with porous material, belong to the river itself, and partake of its current. The stream frequently—particularly in a dry season—will run more underground than on the surface; which is proved by the familiar fact that it will often disappear for distances more or less great, leaving the channel dry, and re-appear again in the channel below with its regular current. It is plain, when we consider this, that all drainage, all liquids of every kind from privies, open sewers, rain, etc., that soak into such a soil, become at once part of the flowing subterranean stream, and will flow *through the wells* themselves. The only variation in effect from the throwing of such effete liquids directly into the stream, is that in the latter case they have some chance of being consumed and rendered innoxious by oxygen, fish and vegetation, but, in the other case, little or none. These simple facts might, could and should, be taught to children in schools. Increase of population throughout country towns and villages will, probably, in time, cause the iron hand of necessity to be felt, and lead to increase of knowledge in these matters.

It is presumed that the canal, when passing Dover, can easily be kept separate from the Rockaway, and that such water as may be taken in from the stream may be derived from above that town, where the Rockaway is, unmistakeably, a pure mountain stream, coming down in two branches from wild and almost unsettled districts —one from the Longwood Valley, and the other from Denmark Valley and Green Lake, a lake which is the highest water in the State (1,044 feet above tide, or 130 feet higher than Lake Hopatcong). No sample was secured from this upper Rockaway, as it was assumed that it would be identical with the water of Lake Hopatcong, with whose tributaries some of its own interlace. This is now a subject of regret, as the Hopatcong water was found, by the analysis, to possess a certain peculiarity, as set forth below.

6. *Lake Hopatcong.*—As before stated, the visit to Lake Hopatcong was made upon a day which had been preceded (the night before) by a tremendous rain, which raised the level of the lake two inches, according to the statement of the lock-keeper at the feeder.

It was, therefore, thought interesting to take, in addition to the sample from the gate by the lock into the feeder, another sample from the margin of the lake, to determine the effect of the wash from the soil of the surrounding country. It will be observed—(No. 6), that this maginal water had a very different composition from that of the bosom of the Lake.

With regard to the latter, it may be interesting to compare the total solid contents with that of a few other lakes:

Lake Hopatcong,	1.79
Bala Lake, Wales,	1.63
Loch Katrine, (supplies Glasgow)	1.63
Norwich, Conn., Reservoir,	1.84
Cochituate Lake,	3.11
Lough Valley, Ireland, (supplies Dublin)	3.11
Croton Lake,	4.78
Geneva Lake, Switzerland,	8.87
Lake Ontario,	6.01
Lake Erie,	6.49
Lake Michigan,	6.68

[The analysis of Bala Lake, in Wales, here quoted from, was made by Frankland and Odling. Another analyst, R. H. Smith (possibly at a different season) obtained a very different result—2.65 grains per U. S. Gallon; and of this latter no less than 0.589 was chlorine—more than five times that in Lake Hopatcong. The Rhine, at Basle, in Switzerland, fed by the drainage of the Alps and the melting glaciers, while containing 9.88 grains of total dissolved matters per U. S. Gallon, has but 0.087 of chlorine. This is the purest natural water, so far as chlorine is concerned, that I have ever heard of. It will be seen that Hopatcong approaches it—containing but 0.014 grain more per gallon.]

These few examples are sufficient to show that this water is among the purest of lake waters. But still, on examining the figures of the analysis, a strange anomaly appears. I refer to the existence of *nitrates* in this mountain lake, in what may be called a large proportion. Of the fact there can be no shadow of doubt. The figures given are the mean of three well-concurrent analyses on three separate portions of the sample, collected by myself and sealed up in a chemically clean glass-stoppered bottle, and never opened until the analyses were begun. The presence and origin of these nitrates in Lake Hopatcong are mysteries to me at present. The only suppo-

sition I can make is that they exist in the water in the form of what are called nitro-humates, derived from peaty or decomposing *vegetable* matter. This is totally at war with the passage from Frankland, quoted on a previous page. It is to be borne in mind that, however produced, these nitrates are perfectly innocuous, and, in such minute quantities indeed, perfectly inert. The idea of their derivation from animal matter (unless from *dead fish*—an inadmissible idea) seems preposterous, and the possibility of drainage contamination in this lake, even if a supposable case, is negatived by the other figures obtained (See columns 9, 10, 11, and 12, of Table I.)

I observe that in an analysis of Loch Katrine, cited by Wanklyn and Chapman, the nitrogen existing as nitrates is given at 0·00031 milligramme per litre, equal to 0·06 grain of nitric acid per U. S. gallon. This is but one-sixth that in Hopatcong, but shows, nevertheless, that a mountain lake *may* contain nitrates. In any case the nitrate test is proved, in the case of mountain lakes and streams, in this country at least, to be of no use as *positive* evidence of sewage contamination, though *negatively* it may still be of value.

I have already stated, generally, the view to which my field and laboratory work jointly have impelled me, regarding a gravity low-service supply for your two cities, for the low-lying portions, where the main supply for business, manufacturing and steam purposes—as well as for fires, is required. I shall now say, that both Science and Nature appear to me to point clearly—as the source of a *high-service* supply of water from the hills, among the purest in th world, for drinking, washing and cooking uses, sufficient for all time, for Bergen Hill and the higher parts of Newark—to the elevated district comprising the united water-sheds of Lake Hopatcong and the upper Rockaway, above Dover. I have carefully marked out and measured the joint area of these two water-sheds. It forms a somewhat regular oblong parallelogram, twelve miles by six, or seventy-two square miles, which would give an average daily supply, the year round, of fully eighty million gallons. One month's flow, or less, during seasons of flood, would fill a reservoir as large as the new and huge Croton reservoir at Boyd's Corners, which might be located somewhere among the hills about Boonton or Montville, and to which the Hopatcong water and the Rockaway, above Dover, could be conducted through the canal. The piping required to take the water from such a reservoir to Belleville would be about sixteen miles in length, as the crow flies.

7. *The Croton Water.*—The Croton and its branches rise from and flow through a country identical in geological character with that traversed by the Rockaway, Pequannock and Ramapo, but it nevertheless receives the drainage from all the towns for twenty-five miles along the Harlem Railroad, besides a good many other settlements and farming districts scattered throughout its water-shed. I was led, therefore, to anticipate some interest from a few comparative, though partial tests, of samples from the New York hydrants. The results (Nos. 14 and 15) appear to show that our water of the Lower Passaic, even with all *its* contaminations, does not *as yet* suffer much in a comparison with the Croton. I would call attention particularly to the comparative chlorine tests.

Still, it is evident we have it within our power to improve *very greatly* on this, and it is to be borne in mind that *purity of water-supply* has already been—and in the future is to be, to a far greater extent—a paramount element of prosperity in a city. Those who conduce to progress in this respect, are eminently entitled to be enrolled among the benefactors of their community. If we are wise, we will take time by the forelock, and not wait for the Rider on the Pale Horse to come and *drive* us to our duty with some terrible death-dealing scourge.

8. *Pollution of Town Wells and Pumps.*—The members of your Honorable Commission are doubtless all familiar with much of the literature of this topic. I shall not go over, therefore, the well-known historical facts which are now so abundantly on record, and which show that epidemic diseases have been on numerous occasions propagated throughout whole communities by the water from a well or pump that had become contaminated by drainage. I might, however, cite here one case that has occurred in the United States within the last month. It was reported but a few weeks since from Davenport, Iowa, where nineteen deaths from cholera (or what passed for it) had occurred at the time within two days, that "nearly all of the cases may be traced to the suicidal use of water from the wells below the bluffs, which are little else than reservoirs of poison from sewage."

My attention was called to this subject in a conversation with his Honor Mayor Ricord, who stated that more than one quarter of the inhabitants of Newark still used well-water.* Knowing from the character of the soil in Newark, chiefly porous fluviatile sands and

* I am informed that this is the case also in Paterson, where similar dangers must be constantly impending—in view of the similar formations underlying that city—even to an extent more marked than at Newark.

glacial drift, that this must be very unsafe, I requested Mr. Bailey to designate two or three of the public pumps most resorted to, that I might make some examinations. He indicated three, from which were obtained the samples whose contents are specified in Table I (Nos. 18, 19 and 20). Without occupying space with minute discussion, I shall only direct attention to the amount of common salt in Nos. 18 and 19 (column 12), about five grains to the gallon, of an ingredient which cannot be traced to any other source than infiltration of urine, of man or beast, or both. No. 20 is not so bad. It appears to me that strict prudence should prompt the closing of wells Nos. 18 and 19, and of all others that may be found to be receptacles of ooze and soakage from the contaminated soil under the city.

9. *Brief Remarks on Sewage-Pollution of Rivers.*—This is also a subject that has been so much bewritten, that it may not be advisable for me to expend much space upon it.

The class of scientists who study microscopic fungi, mycologists (in common with many distinguished scientific physicians), are now settling down to the belief that most epidemic and epizootic diseases are accompanied (as *causes*, not merely as effects) by certain fungoid growths; in other words, that these diseases are produced by vegetable parasites. When these fungi take root in animal tissues, they develop into abnormal and monstrous forms, which have not been recognized until lately; but it is now known that the spores discharged (by millions of millions, it may be) with the excreta, when cultivated *outside* the body, come back again to their normal forms, and the fungi are recognizable. Thus, in common dysentery and cholera morbus, the spores, when replanted, produce a common fungoid parasite *wheat*, while during the fearful Asiatic cholera the spores produce a parasite of the East Indian *rice-plant*. These facts (if they must be admitted as such, which seems inevitable) are suggestive with regard to sewage contamination of rivers. One case of cholera brought to Paterson, or any one of the towns lying on the upper Passaic, might fill the whole river with the living seeds of the pestilence. A like propagation would take place from Newark throughout Jersey City and Hoboken, and even throughout Newark itself! I am aware that these are appalling considerations, and may be rejected by some as contingencies too remote and dreadful to be possible; but human experience, alas, will not countenance any such puerile view as this. We must stare these horrors sternly in the face, bring all our science

to bear, and study prevention, rather than wait till called upon to endure the evil when it shall have passed beyond our cure.

Conclusions.—1. In addition to the rapid agencies of self-purification and nitrification, by oxidation, that were shown by the analyses of last winter to act in the Passaic water, the analyses of the past summer indicate, during the latter season, additional powerful agencies in the enormous amount of vegetable and animal life inhabiting this water, which co-operate in consuming the effete matter with surprising rapidity.

2. These last two agencies are unreliable, and may at any time fail us. It is probable that the limit is even now about reached, at which the excess of material for the nourishment of these beings—or rather the inevitably poisonous products of the putrefaction of this excess—will engender all at once some deadly epidemic, or rather *epi-ichthyic* disease, which will destroy the fish, as is well known to have always resulted, sooner or later, in similar cases.

3. The analysis of Jersey City reservoir water of August 9th shows that even now there are times when these consuming agencies fail to come fully up to the mark, so that the average of putrefiable matter in the water, as distributed to consumers, rises to a proportion that should cause deep disquietude.

4. The large indications of matter of animal origin in solution at low-tide at the Newark pumps at Belleville, overthrows the plan brought forward in the Chemical Report of last March, that the water be conveyed to the pumps from a point higher up the river.

5. The water above the falls at Paterson does not present, at least in summer, the purity that appears desirable in a water-supply to be selected and adopted for all time, especially when it is remembered that the main Passaic receives a large and constantly increasing amount of drainage from towns, country and factories, as well as much swamp-ooze.

6. The Morris Canal, on the long level, above Paterson, extending to Bloomfield, much excels in purity the water above the falls at Paterson (see Table VI), containing but about one-half the volatile matter, nitrates, animal matter and chlorine.

7. Were the incessant surging against the banks of the canal, by passing boats, to be stopped, its water would quickly assume a limpidity or clearness equal to that of the river above the falls.

8. The canal feeder at Pompton Plains, which is capable of draining more than one-third of the whole Passaic water-shed—and which

comes down from a country very little cultivated and sparsely settled —brings water which is far beyond that of Passaic Falls in purity; the amount of total solids in the feeder to that in the upper Passaic being as 1 to 1·38, the amount of nitrates as 1 to 2·4 and the amount of chlorine as 1 to 2·17.

9. Were the main canal, above the Pompton feeder, protected from contamination by the towns and villages along the valley of the Rockaway, and its influx of water confined to the Hopatcong feeder and the Rockaway above Dover, it is probable, indeed reasonably certain, that its water would acquire a purity even much greater than that of the Pompton feeder.

10. Lake Hopatcong is scarce surpassed in purity by any mountain lake whose analysis is on record, being very closely equal to the celebrated Loch Katrine that supplies Glasgow.

11. It may be accepted that the upper Rockaway, above Dover, coming from the same country, and fed moreover in part by Green Lake, 130 feet higher than Hopatcong itself, must be at least equally as pure as the latter.

12. The combined water-shed of Hopatcong and the Rockaway above Dover, measures 72 square miles; equivalent to an average daily supply of at least eighty million gallons, or say, in round numbers, 30,000,000,000 gallons per year, of water ranking among the purest in the world.

13. Were a large reservoir constructed among the hills of the highlands, somewhere about Boonton or Montville, to which this water could be brought through the canal, from fifteen to sixteen miles of piping would carry it to Belleville, with a head sufficient to raise it to the highest parts of Newark, or of Bergen Hill and the Palisades.

14. At the same time the Pompton feeder could deliver, at Bloomfield, through the long level, for all business, steam and manufacturing purposes, such copious supplies of water, equal in purity to any river of equal volume in the United States—for example, of fully twice the purity of the Croton—that your cities would at once become, in this truest and most beneficent of all wealth of cities, quite as rich as Imperial Rome of old, in her halcyon days.*

15. In conclusion, taking in view all the results of my labors dur-

* Rome, under the Emperors, when she was mistress of the civilized world, had a daily supply of pure water for every man, woman and child of more than three hundred gallons.

ing the year past, in the field and in the laboratory, I cannot hesitate to enounce, as my professional opinion, that if it is true that the opportunity now offers (as is stated to me) for your honorable Commission to convert the Morris canal from what is said to be an unprofitable channel of navigation, into a channel of pure water-supply for the great cities now growing up around us, this opportunity should be availed of immediately, without any dangerous delay.

All of which is respectfully submitted.

HENRY WURTZ.

On Chinese and Japanese Bronzes.—In the Paris Exposition of 1869, many bronzes from China and Japan were exhibited, which were of remarkable beauty, and which attracted great attention on account of the dead black color of their patina. The composition of these bronzes was, at that time, unknown. Lately, however, M. Henry Morin, of the Paris Conservatoire, has made an investigation of these bronzes, the results of which he has communicated to the Academy. They are interesting as well from a metallurgical as from a scientific point of view. What chiefly distinguishes these Chinese and Japanese bronzes is the large quantity of lead which they contain, in comparison with that used in European bronzes. On an average these bronzes were found to be composed of copper, eighty parts; lead, ten parts; tin, four parts; zinc, two parts; the remaining four parts consisting of iron, nickel, arsenic, sulphur and gold. In certain of the specimens analyzed, the lead much exceeded the amount above given, rising sometimes to even twenty per cent; but in these specimens, the content of tin was also increased, rising even to seven per cent. Such an alloy, however, has but little strength. The bronzes containing ten per cent. of lead possess rather remarkable qualities. They can be cast with facility, they are close-grained, and they take very quickly, when heated in a muffle, the black patina above mentioned. This patina, which had been supposed to be due to a special varnish, belongs really to the metal itself, being produced as above. To obtain successful castings with these bronzes, it is necessary that the objects produced should be quite thin.

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